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[656]

Competition by roads, waterways and airways.

IV (1).

We publish hereafter, in connection with the competition to which railways are subjected, further information received, with regard to Belgium, France, Japan, Argentine, India and British East Africa.

BELGIUM.

Proposed Belgian law on the co-ordination of transport by rail and road.

GENERALITIES.

On the 28th March, 1934, Mr. Forthomme, then Minister of Transport, laid before the Senate the draft of a *Bill for the better co-ordination of transport by road and rail.*

This bill is divided into two chapters.

Chapter I regulates road transport, while Chapter II aims at freeing the railway from some of the legal requirements it has to observe at the present time.

The two chapters are preceded by an extensive « consideration of motives »; this runs to 22 pages, whereas the bill itself has only 22 clauses.

The explanation for this length lies in the present tendency of Belgian public opinion to oppose all tentatives to interfere with commercial liberty. It considers *a priori* that the transport industry is like any other industry, and should be free to enter into agreements when neither public order nor custom are affected thereby.

Public opinion is oblivious of the fact that by far the most important carrier, the railway, is not free. A law of the 25th August, 1891, forbids it what is allowed to road transport undertakings.

In the case of the railway, agreements do not take the place of the law. The terms of the only valid agreement that could be made have been drawn up by the legislature which, at the same time, imposed obligations and restrictions which can be explained by the monopoly railway transport practically enjoyed at that time.

The authors of the « International Convention dealing with the transport of goods by railway » followed the same lines of thought.

The railway is consequently unfavourably placed with regard to its competitor, the road haulier.

Basing their reasoning on these facts, the Belgian railways have summed up the problem in the following alternatives :

either grant the railways the freedom by which road transport undertakings profit,

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(1) See *Bulletin of the Railway Congress*, June to August, 1934.

or impose on the road haulier the same obligations and restrictions as the railway has to contend with.

The Minister of Transport fully recognised the justice of this conclusion.

The consideration of the motives for the draft bill states in fact :

> If we want to place the two methods of transport in a comparable, if not absolutely similar, position, the railway, as has already been shown on several occasions, must be freed still further from the various now unjustifiable burdens and charges falling upon it.

The draft bill, however, does not altogether conform to this argument of the railways, as we shall see further on. Nevertheless it takes as an axiom the need for regulating road transport :

> It would serve no useful purpose to deal at length with the increasingly urgent necessity for co-ordinating the methods of transport. In this connection the most important problem in every country is that of the railway and the road.

This need for co-ordination, which is affirmed in the consideration of the motives for the bill, is nevertheless disputed. It would have been a good thing had the point been developed more amply in order to make it clear to public opinion that the absence of all regulation of road transport can only be harmful to the general interest.

The existence of two methods of transport to cover the goods traffic between two places is a luxury, and consequently is always harmful.

It is especially to be deplored when economies must be effected in every field. States cannot afford the luxury of increasing their means of production when their sales are constantly falling off. Consequently the Minister affirms that the object of the law is, in particular, to avoid waste and duplication. In this respect he agrees with the International Chamber of Commerce whose « independent experts » have recognised that it is impossible to let free competition solve the road and railway problem.

It is to be hoped that Belgian public opinion will realise that the experts of the International Chamber of Commerce, in drawing up their conclusions, were not inspired by the desire to give the railway a privileged position. It is indisputable that their conclusions were largely due to questions of exchanges.

In his consideration of motives, the Minister of Transport recognises that the railways, in spite of the development of road transport, are still indispensable to the economic activity of the country. The cost price of transport by rail is definitely lower than that of road transport. If, in spite of this, the motor succeeds in taking away traffic from the railway it is because the rates system used by the latter is based, not on the cost price, but on the need to assist the transport of low-value goods which could not pay carriage charges on the higher rates.

The Minister notes that :

> The railway rates are so designed that the working expenses are covered in a general way by transporting goods at rates in proportion to their value... The loss suffered by the railway, of further categories of goods taken from it by lorry transport, will inevitably lead to increased rates for heavy low-value goods, or even make it necessary to give up such transports completely. Needless to say this would be the end of many of the great national industries and the ruin of a large part of the country's exports.

Consequently, the railways must be allowed to live and road motor transport must not be done away with.

With a view to conciliating these two demands the Minister of Transport based his draft on the law of the 21st March, 1932, regulating the transport of passengers by road.

This law requires all public road passenger services, whether by omnibus or motor coach, to be licensed. No license is required when the passenger himself decides the destination and itinerary of the journey.

The Minister of Transport has based on similar principles his bill for dealing with goods transport.

FIRST CHAPTER OF THE BILL.

Transport of goods by road.

The first clause is the essential one of the proposed bill :

> No one can carry out the transport of goods on behalf of another party, for payment, by means of motor vehicles or by independent railless mechanical traction without a license obtained in conformity with the present bill.

The Government, by requiring a license to be obtained before goods can be carried by road on behalf of a third party, has admitted that the transport industry is one of public interest.

> The public, it is stated in the considerations, is entitled to require public road transport services to be carried out under the best possible conditions of security and regularity. It must be given the assurance that in the future such transports will be carried out with the same guarantees as when using the railway.

A license must be obtained by foreign as well as national transport undertakings, but will not be required in the case of the manufacturer or trader who carries his own goods in his own lorries.

> Every manufacturer and every trader owning one or several lorries or vans can continue to make use of them for his business requirements, without license.

In the same way, farm produce can be carried from the farm to the fields and vice versa without a license, as can transport within the limits of a port.

The licenses are issued by a new organisation known as the « Road Transport Office » the head of which is appointed by the King.

The draft bill does not define the grounds upon which the Road Transport Office shall grant or refuse to grant a license. It merely states that « when requests for a license are considered, the needs of the traffic and the existing methods of transport between the places or whithin the district concerned must be taken into account.

The licenses are granted for a maximum period of three years and can be withdrawn if the obligations imposed on the transporter are infringed.

A provisional license can be granted while awaiting the result of the investigation the Road Transport Office has to carry out.

The decisions of the Road Transport Office may be appealed against.

Anyone who feels he has suffered loss through a decision of this Office can appeal to a higher body, the « Appeal Committee ». The decision is suspended on an appeal being made, but such an appeal must be lodged within fifteen days of the publication of the Road Transport Office's decision, or it will not be admitted.

The « Appeal Committee » is composed of a president and two members nominated by the King for a period of six years because of their particular competency in the matter.

Members of the Government or of the Legislative Chambers cannot be nominated to this Committee. They are likewise debarred therefrom during the two years following the expiration of their holding office.

A general regulation, approved by the King, will lay down the different instructions necessary to carry out the law. This regulation mentions certain questions as examples, but without limiting them. Among those mentioned one is of particular importance :

« the obligations imposed on carriers in the interest of users and for the safety of road transport. »

As the consideration of motives stresses, this clause gives the Government full control over the transport policy.

The costs of the Road Transport Office, the Appeal Committee and the Control may be covered by imposing a « license tax ».

Any infringement of the law and the general regulations issued to carry it out will be punished, if necessary, by cancelling the license. Such offences are punishable in addition by one to eight days' imprisonment and a fine of five to two hundred francs. Should the offence be repeated these penalties may be doubled.

If the penalties are inflicted for operating a service without a license, they cannot be subject to conditions.

The sums due from the guilty party for fines and costs may be recovered by the forced sale of the vehicles used to break the law, even if these vehicles are not owned by the defendent.

Finally the proposed law allows the Belgian National Railways Company and the Belgian National Light Railways Company to operate road motor goods services or to hold shares in such services.

CHAPTER II.

Railway.

Chapter II modifies the laws relating to railway transport to the profit of the railway.

As we have said above, the railway is authorised to favour its regular customers, in supplying stock and forwarding their consignments.

Below we give the new wording of clauses 28 and 32 of the law of the 25th August, 1891. The new features in the proposed law are shown in italics.

Clause 28. — The administration must despatch consignments in the order in which they are received, except when preference is given to certain consignments for reasons of public interest or for working requirements.

Priority may, however, be granted to consignors who deal regularly with the railway.

Clause 32. — When loading cannot take place immediately, requests for transport facilities are entered in a special register, and in addition should the consignor so wish, a form is issued showing the day and time they were handed over to the railway.

Priority in supplying stock may be granted to consignors dealing regularly with the railway.

As the consideration of motives observes, the latitude these two additions give the railway is only relative, as the railway must in every case keep to the booked times for supplying stock and delivery of consignments laid down by the law and in the regulations.

The Government has refused the railways full liberty to draw up their rates, such as road hauliers enjoy.

The consideration of motives states in this connection :

Should we go even further and delete clause 15 of the law of 1891 (1) as has been suggested? The Government does not think so. To grant such liberty to the railway in the matter of rates, even if certain restrictions were imposed, would mean that the Belgian National Railways Company could in future make private agreements with any particular customer, and refuse their application to others. Such an idea is incompatible with the spirit of public service and the need for regulating transport... If granted absolute freedom as regard making and applying the rates, the National Railways Company would be in a position to wield such an influence that certain people might be tempted to see favouritism or arbitrariness even where only legitimate adjustments of rates were being made. We cannot take such a risk.

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(1) This clause is exactly the same as clause 10 of the C.I.M. (International Convention for the transport of goods by railway — Berne).

Dealing with the operation properly speaking of the railway, the proposed bill gives the Government the right to allow the Belgian National Railways Company to substitute motor transport for railway transport in the case of both passenger and goods services.

Road transport passenger services substituted by the railway company have not to meet the obligations laid down in the law of the 21st March, 1932, on public omnibus and motor coach services. Neither has the National Railways Company, in order to organise such services, to obtain the authorisation of the subordinate authorities, i. e. the provincial or local authorities according to the case, nor has its application to be tendered out. The State, provinces, and communes may, however, levy a tax upon such services for the upkeep of the roads.

This clause is the same as that included in the law of the 21st March, 1932, dealing with passenger transport services organised by the Belgian National Light Railways Company.

If a line or section of a line is found to be no longer justified, owing to little traffic, the Government may authorise the Belgian National Railways Company to close it. This must be taken as meaning that the line or section of line can be taken up. To meet public opinion, which is usually against suppressing railway facilities, the consideration of motives says: « such cases will be very rare, at least during the first few years. In addition, all interested parties will be consulted before making any decision. »

As the operation of the railway is governed by regulations the most modern of which dates from 1868, it goes without saying it often finds itself up against regulations no longer justified by present-day conditions. To obtain a more flexible operation, better adapted to the needs of the time, the Government may modify the regulations. However, as these are two-sided agreements from the juridical point of view, any modification must be agreed by the two parties concerned : the Government acting in the name of the State, and the concession-holder or operator.

Finally the proposed bill provides that road transport services organised by the railway shall not come within the scope of chapter II of the law of the 25th August, 1891. This means that such road services are not subject to the legal requirements binding transport by railway.

This appears to be superfluous in view of the alteration made to the wording of chapter II of the law of the 25th August, 1891. It appears, however, that the lawyers are of the opinion that it is the standing of the operator and not the nature of his working which must be considered in order to determine whether transport contracts come under chapter I or chapter II of the law of 1891.

The wording of the proposed bill removes the possibility of any such argument.

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FRANCE.

The information given below is taken from a note the Management Committee of the French Main Line Railways has been good enough to send us.

The data given in this very complete and comprehensive note has been given in part already in the article by Mr. Brion, which was reprinted from the *Revue Générale des Chemins de fer* in the August, 1934, issue of the *Bulletin*. This article included in particular the commercial measures taken by the Railways and the commentaries on the decrees of the 30th December, 1933, and 19th January, 1934. In spite of this we will give the text of the note as it stands in order to give a complete picture of the matter, and as an appendix we will give the two decrees in question as well as the more recent decree of the 19th April, 1934, dealing with the co-ordination of railway and road transport, and the decree of the 15th May, 1934, on railway and waterway co-ordination.

I. — ROAD COMPETITION.

A. — Statistics relating to passenger competition: Length in km. (in miles) of road motor services in regular operation in France.

	Alsace-Lorraine.	Est.	State.	Midi.	Nord.	Paris-Orleans.	P. L. M.
1. Permanent services.							
a) By the railways.	None.	None.	None.	None.	None.	None.	None.
b) By concession-holders on behalf of the railways.	79 (*49*)	1 331 (*827*)	2 300 (*1 429*)	77 (*47.8*)	488 (*303*)	4 838 (*3 006*)	5 577 (*3 465*)
c) By other public undertakings.	8 424 (*5 235*)	11 330 (*7 040*)	26 000 (*16 156*)	36 614 (*22 751*)	16 652 (*10 347*)	30 000 (*18 641*)	24 000 (*14 913*)
2. Temporary services.							
a) By the railways.	None.	None.	None.	None.	None.	None.	None.
b) By concession-holders on behalf of the railways.	1 282 (*797*)	2 940 (*1 827*)	10 000 (*6 214*)	1 818 (*1 130*)	93 (*58*)	21 800 (*13 546*)	21 800 (*13 546*)

B. — Statistics relating to competition in goods transport. Number of lorries licensed in France on the 31st December, 1933: 422 086.

C. — Measures taken by the French Railways to fight motor competition.

1. Technical measures:

a) *Organisation of motor services.*

In 1928, the French Main Line Railways, asked by the Minister of Public Works to see what could be done to protect the railways from competition, set up Ancilliary Motor Transport Companies whose statutes were approved by the Minister, subject to the condition that the Railways held the majority of shares.

These Companies organised transport services by road as feeders or supplementary services to the railway but, already in

1929, they came under the very stringent control of the Higher Authorities from whom they had to obtain an authorisation for any new service they wished to start. Consequently they found themselves handicapped as compared with their rivals, as other motor transport undertakings were completely free from control before the 20th April last, when the decree relating to co-ordination referred to in § D was promulgated.

b) *Conditions of admission to the trains.*

The Railways have abolished many of the conditions governing admission to fast and express trains, so as to facilitate as far as possible the use of such trains by the public, even for short journeys.

c) *Increased train speeds.*

The Railways have for some years taken steps to improve their services.

In particular, since 1933 passenger trains have all been speeded up and this has enabled much time to be saved on the journey in the case of both long-distance and local trains.

Certain railways have introduced extra-light trains with a small number of coaches which run at the maximum speed and stop for the minimum time at stations.

The speed of the express trains has also been accelerated though well within the limit of safe working.

These accelerations have made it possible to give many new connections and to improve existing connections by reducing the intervals at connecting points.

The speed of goods trains has also been generally accelerated, thanks to the fitting of continuous brakes to the ordinary goods stock.

d) *Introduction of rail motor cars.*

In addition, the Main Line Companies have put into service a certain number of petrol or gas-oil rail motor coaches, with pneumatic or metal tyres, either for fast services between important places or to replace steam trains on certain secondary lines.

e) *Through services.*

The introduction of rail motor coaches has made it possible to set up new through services between certain places where the steam train service meant changing trains.

f) *Containers.*

In the case of goods transport, the railways are endeavouring to increase the use of containers by extending on the one hand the measures taken for registering appliances of this kind belonging to individual owners, and on the other hand by increasing their own stock of containers, which are put at the disposal of the public under particularly advantageous conditions. The rates for traffic carried in this way are based on the net weight of the goods and very reduced rates are charged for the return of empty containers.

g) *Door to door transport.*

The collection and delivery of parcels from door to door has been improved by extending the cartage services, or by employing grouping agencies.

h) *Other measures.*

The stations are opened for longer hours.

Grouping agencies are given covered sheds in the stations for use as depots and for sorting their goods.

Motor services have been set up in the Paris suburbs and at the terminal stations on the systems in order to accelerate the delivery of express parcels traffic.

2. Commercial measures.

a) *Rating measures.*

Rating measures have also been taken by the railways to retain the transport of certain goods threatened by motor competition ; such measures have usually included the following :

— Introduction of standard reduced rates from station to station for contracted traffic, with regularity premiums in the case of definite traffic currents ;

— Introduction of reduced rates to grouping agencies with refunds based on the tonnage handed in by them.

Special rates have also been introduced, amongst which, apart from rates applying to certain given kinds of goods, mention may be made of:

— The wagon-kilometre rate, which enables consignors to hire one or several wagons between given places for three months. At the end of the period the contract can be renewed.

The carriage charge is based on the number of kilometres run by the wagon, whether loaded or empty.

— Express parcels rates intended to recover parcels traffic lost to fast road transport services.

Among other rating measures taken by the railways mention may be made of :

— the lowering in certain cases of the tonnage conditions ;

— the granting of regularity premiums and tonnage rebates ;

— introduction of contracting arrangements in certain rates schedules.

b) *Issue of combined railway-road tickets.*

Through registration of luggage.

Some stations issue for specified motor services combined tickets, one coupon covering the railway journey and the other the road journey.

With these tickets, luggage can be registered for the whole journey from start to finish.

This encourages passengers to use the services officially connecting with the railway, and as there is no break in their journey nor in that of their luggage the attraction from this aspect of a through journey by road is diminished.

D. — Modifications in the laws likely to affect the relationships between the railways and motor services.

1. Decree of the 30th December, 1933, determining the conditions under which the Main Line Railways can be relieved from the prescriptions of their concession deeds and agreements actually in force *(Appendix A).*

This decree lays down in particular :

1. that rates which have been lowered can be restored to their former level after a period of three months in the case of both goods and passenger rates (formerly the period was three months in the case of passenger rates and one year in the case of goods rates) ;

2. alterations can be put into force provisionally by the railways without express approval (formerly approval was necessary) :

a) one month after they have been published in the *Official Journal* if the Minister has not raised any objection ;

b) after a period of two months calculated under the same conditions as (*a*) above in the case of alterations which could not be put into force at the end of one month owing to the opposition of the Minister, if the latter had not notified the railways of his approval or refusal of the said alterations ;

3. that the rates to be applied may give a maximum and minimum charge. The regulations given under (1) and (2)

above apply to such rates. On the other hand, the maximum and minimum charges must be submitted to the Minister ; they can be applied after a period of 15 days from the time they were submitted, if the Minister has raised no objection.

These new arrangements enable the Railways to protect their traffic from competition with greater efficacy, especially from competition by road transport undertakings.

2. Decree of the 19th January, 1934, fixing the conditions under which the Main Line Railways may be relieved from the requirements of the law, the bylaws and conventions in connection with technical or commercial operating *(Appendix B).*

The text of this decree calls for the following commentary :

Bases of charges and minimum rates (clause 3). — The Minister of Public Works can authorise the railways to fix their rates otherwise than on the number of kilometres and fractions of weight laid down in the concession deeds. This clause should in particular enable the railways to introduce special parcels rates. Furthermore it is completed by part of clause 8 dealing with *a single class of goods traffic.* This clause lays down that the Minister can authorise the Railways to substitute for the present fast and slow goods rates, a single class as regards rates, transit times, and other conditions, as well as, if need be, for the present rates applied to all parcels, packages, or excess luggage weighing separately 40 kgr. (88 lb.) or under.

Order in which goods must be dispatched (clause 7). — The railways are no longer obliged to dispatch goods to the same destination in the order in which they were booked at the station, unless these goods come under the same rates and do not require any special stock. This modification appreciably lessens the burden the obligation to carry lays upon the railway.

Receipts (clause 7). — The regulation by which a receipt must be sent to the consignor has been modified in so far that the receipt need not be delivered for 24 hours after the goods were received. This should enable the accountancy to be centralised in the centre-stations. It is moreover laid down that in such a case a provisional notice shall be delivered under conditions to be fixed by the Minister of Public Works, at the suggestion of the Railways.

Despatch and transit times by railway (clause 8). — *Express traffic.* — The transit time instead of being counted from the starting time of the first passenger train, with all classes of carriages going to the same destination as the consignment, will be calculated according to the timings of trains selected by the Minister of Public Works at the suggestion of the Railways. These regulations will come into force after fifteen days unless the Minister raises an objection.

Slow traffic. — The transit time is still based from the day following the day the consignment was received, but whereas the regulations laid down that the railway could extend this time to two days, the decree states that the time may be increased by the number of days required to provide stock of the necessary type.

On the other hand, the slow traffic transit times are fixed henceforth at 24 hours per 200 km. (124 miles) or part thereof, whereas it used to be 24 hours per 200 km. for the main lines and 24 hours per 125 km. (77.7 miles) for the secondary lines.

Transit times for services replacing railway services (clause 8). — The Minister will fix, at the suggestion of the Railways, the transit times to be applied to services replacing railway services ; alterations to the transit times will come into force after fifteen days, if the Minister raises no objection.

The Minister may authorise the railways to reduce the weight of 30 kgr. (66 lb.) of luggage per passenger carried free of charge by such services.

Rail motor cars (clause 9). — The above two paragraphs apply equally to rail motor car services.

In the case of passenger transport by means of such vehicles, the railways ought, moreover, to take steps to meet all *expected* traffic ; this prescription saves them from being obliged to carry an abnormal rush of passengers should this be due to *unexpected* circumstances.

The obligation to carry goods is limited to the nature, dimensions and tonnage of the parcels which the stock can carry. The Minister, moreover, lays down which rail motor coaches and parcels trains should carry small consignments.

Number of trains that must be run (clause 12). — The Minister may authorise the Railways to run, on certain lines or sections of line, fewer trains than the minimum of three a day in each direction, laid down in the Agreements of 1883.

These are the principal amendements made to the operating conditions of the French Main Line Railways, by the decree of the 19th January, 1934.

3. Decree of the 19th April, 1934, relating to the co-ordination of railway and road transport *(Appendix C)*.

After a very thorough investigation into the matter by the National Economic Council, the law of the 19th April, 1934, laid down administrative regulations of a public nature, for the first time in France, in order to limit the competition between the railway and the road.

It must be remembered that there are two classes of road motor trasnport in France : the subsidised undertakings, which receive financial assistance from the State, a Département, or Commune, and in return undertake to give a certain service under certain conditions, as to regular services, timetables and rates ; and the free transport undertakings which can be formed and operated with no other condition than that of observing the police regulations.

a) *Preliminary measures.*

The law of the 19th April, 1934, first of all makes provision for a census of all operators of free public motor services by obliging them to report within fifteen days to the Prefect of their Département, stating in particular :

1. the service given (route, timetables, rates) ;
2. nature of the traffic carried (passenger or goods) ;
3. description of stock utilised ;
4. the professional organisation or organisations to which the service is affiliated.

The decree lays down clearly that by « public transport » must be understood « all services offered the public, with a commercial object, for the transport of passengers or goods » excluding in all cases exceptional transport of passengers to meet requirements that do not arise regularly.

In addition from the date of publication of the above mentioned decree, *all new road transport services are provisionally forbidden.*

b) *Co-ordination.*

In order to achieve co-ordination properly speaking of railway and road transport, a « Co-ordination Commission » has been set up in the Ministry of Public Works, consisting of :

1 expert from the Main Line Railways;
1 expert from the Secondary Railways;
1 expert from subsidised motor transport undertakings;
1 expert from free motor transport undertakings (passenger);
1 expert from free motor transport undertakings (goods).

Should the professional organisations of the motor transport undertakings fail to agree among themselves, the Minister himself will nominate the experts.

The Commission will include, in addition, an arbitrator appointed unanimously by the five experts, or should they fail to agree, by the Minister.

It will be the duty of this Co-ordination Commission to bring about direct agreements, in the various zones, between the railway and the road hauliers concerned, for the organisation of public transport of passengers and goods.

If no agreement can be arrived at, the arbitrator will submit to the Minister of Public Works proposals for the maintenance or the modification of the existing services, or for the suppression of certain of them within a time fixed separately for each case, and the setting up of new services.

These agreements or proposals shall come into force when approved by the Minister of Public Works.

The decrees will lay down the time for which the agreements or proposals shall remain valid.

They will oblige road hauliers to observe certain conditions as regards timetables, and the obligation of assuring the service and giving equality of treatment to all users. They must also carry the mails.

After the ministerial orders have been published, all new services will require the authorisation of the Minister of Public Works, which will only be given after the Co-ordination Commission has examined the proposals and the arbitrator has approved them.

As a result of this order, negociations have been begun in different places between the main line railways and the motor transport undertakings ; an agreement has already been arrived at in the case of the Seine-Inférieure region.

II. — COMPETITION FROM WATERWAYS.

A. — Statistics relating to such competition.

GENERAL TABLE SHOWING THE TRAFFIC FOR THE FIRST THREE MONTHS OF 1934
and comparing the tonnage with that the of the previous year.

Tonnage loaded during the first three months. Metric (*Engl.*) tons.		In comparison with 1933.	Tonnage loaded since the beginning of the year Metric (*Engl.*) tons.		In comparison with 1933.
1934	1933	Percentage decrease.	1934	1933	Percentage decrease
11 576 142 (*11 393 300*)	11 609 407 (*11 426 500*)	0.3	11 576 142 (*11 393 300*)	11 609 407 (*11 426 500*)	0.3

B. — Measures taken by the Railway to meet competition from water transport.

By means of special arrangements (contract rates and all-in charges) the railway has been able to keep various currents of traffic much sought by water transport, or to win back traffic originally carried by rail which had gone over to the competing transport.

C. — Modification in legislation likely to affect the relationships between the railway and the waterway.

Decree of the 15th May, 1934, relating to co-ordination between railways and waterways *(Appendix D)*.

By this decree, a Central Co-ordination Committee has been set up at the Ministry of Public Works, assisted by regional commissions, whose duty it is to divide up the traffic between the two methods of transport, making agreements between them whenever possible.

This distribution should reserve for water transport the traffic usually carried in complete boat loads.

From the date of publication of this decree, the transport of miscellaneous goods and the use of boats belonging to new firms must first of all be authorised by the Minister of Public Works.

Likewise the registration of all new boats for inland navigation which could be used for the transport of goods must be authorised by the Minister of Public Works.

III. — COMPETITION FROM AIR TRANSPORT.

A. — Statistics relating to the movement of the main French air services.

1. Passengers carried during the first three months of 1934: 7 542.

2. Parcels, papers, excess luggage carried during the first three months of 1934: 328 899 kgr. (323 Engl. tons).

3. Mails: 50 220 kgr. (49.2 Engl. tons).

B. — Measures taken by the railways to meet this competition :

— general acceleration of all fast trains.

— improvement of international relations by the introduction of new connections.

C. — Modification of legislation likely to affect the relationships between railway and air transport.

Up to the present nothing has been done in this connection.

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APPENDIX A.

Decree of the 30th December, 1933.

Derogations to the concession deeds and conventions as regards rates.

Clause 1. — Derogations to clause 48 of the concession deed and clause 12 of the law of the 9th April, 1898, will be made under the following conditions :

1. The period at the end of which rates which have been lowered can be raised again is fixed at three months, for goods as for passenger traffic, an exception being made in cases in which the application of the reduced rate was originally limited to a shorter period;

2. Proposed new rates shall be advertised a month in advance by posters.

They are also published in the *Official Journal* on the Tuesday after they have been handed in at the Ministry of Public Works (General Management of Railways and Roads) on condition that they were handed in the previous Friday at the latest.

Should the *Official Journal* not be published on that Tuesday on account of a bank holiday or for any other reason, they will be published in the next issue.

The opinion which the Chamber of Commerce, and if need by the Chamber of Agriculture, must express on proposed rates according to clause 12 of the law of the 9th April, 1924, must be received by the Minister of Public Works within 20 days of the publication of the proposed rates in the *Official Journal.*

The rates can be provisionally applied by the railways, without having been expressly approved, if the Minister has not raised any objection at the end of one month from the date they were published in the *Official Journal.*

If the Minister does not approve of the new rates, his decision must be made known within two months of the date of publication. If no decision is given within this time, the rates can be provisionally applied without formal approval.

Without prejudice to the arrangements made in the agreement of 1921, proposed rates can only be rejected after consultation with the Higher Railway Council. This latter must give its opinion after hearing the administration and railway systems, within one month on the proposed rates submitted to it by the Minister;

3. The scales of rates to be applied may indicate the maximum and minimum charges.

In this case the rate to be charged within these maximum and minimum limits must be posted up and communicated to the Minister of Public Works (General Management of Railways and Roads). They can be applied after 15 days from the day they were submitted to the Minister if he has raised no objection.

In this same case, rates that have been lowered can only be raised again after three months, except in cases where the lower rate was originally limited to a shorter period.

Clause 2. — The rates to be applied in the case of services which the railways have been authorised to substitute for railway services will be laid down by the Minister of Public Works, based on the rates proposed by the railways; as laid down in paragraph 3 of clause 1 a maximum and a minimum rate are fixed for carrying passengers and each class of goods.

The rates to be charged the public lie between this maximum and minimum; their application follows the procedure laid down in paragraph 3 of clause 1 above.

The same applies in the case of door to door services, and to connecting services.

When, however, such services are worked by a contractor whose only remuneration is the rates he charges the public, the railways do not have to submit a maximum and minimum rate for ministerial approval. The rates can be applied merely by following the procedure laid down in paragraph 3 of clause 1 above.

In the case of consignments which only go by rail part of the way, the Minister of Public Works may authorise the application of rates covering the whole journey, the amount for the whole journey not being necessarily equal to the sum of the amounts for the railway part and the parts by other means of transport.

In such a case, should the amount properly belonging to the railway lie between the maximum and minimum rates approved by the Minister, for the part of the transport carried out by the railway or its contractors, the application of the amount to be charged for transport for the whole journey only has to conform with the procedure laid down in paragraph 3 of clause 1 above.

Clause 3. — All modifications to rates or charges must be brought to the notice of the public with the date from which they will apply.

Clause 4. — In all cases mentioned in clauses 1 and 2, the rates must be charged without discrimination nor favouritism.

Clause 5. — The procedure laid down in paragraphs 1 and 2 of clause 1 also applies to modification in rates and sundry charges which, according to clauses 43, 47 and 51 of the concession deed are fixed by the Minister of Public Works after submission by the railways.

Clause 6. — The Minister of Public Works is responsible for carrying out the present decree, the terms of which will be published in the *Official Journal.*

APPENDIX B.

Decree of the 19th January, 1934.

Conditions under which the main line public railways can modify the prescriptions of the laws, concession deeds, and conventions affecting their technical and commercial operation.

PART I.

DEROGATIONS TO THE REGULATIONS AFFECTING THE MAIN LINE RAILWAYS.

Clause I. — Derogations to clause 30 of the concession deeds :

Maintenance and possible closing down of railway plant.

The Minister of Public Works can authorise the railways to give up the maintenance, and after investigating the matter, close down railway installations rendered useless by changes in operating methods.

Suspension of railway services.

The Minister of Public Works can authorise the railways to suspend their services on lines or sections of line, either altogether or in part, when he is satisfied that this service is covered by other methods of transport.

Services replacing railway services.

The Minister of Public Works can authorise the railways to have carried out under their control and on their responsibility the service of a line or section of line by another method of transport than the railway and by another route; in this case the railways can be authorised to transfer to offices, depots, or stopping places in the places served, all or part of their station services.

Rolling stock.

Clause 2. — By an alteration to clause 32 of the regulations, the Minister of Public Works can authorise the railways to reduce the number of classes to be provided in passenger carriages.

Bases and minimum rates of charges.

Clause 3. — By an alteration to paragraphs 4 to 9 of clause 42 of the regulations, the Minister of Public Works can authorise the railways : 1. to simplify the rating system, basing it on other factors than the number of kilometres and fractions of weight given in this clause; 2. to modify the minimum rates charged.

Composition of passenger trains.

Clause 4. — By an alteration to paragraph 2 of clause 43 of the regulations, the limitation of the number of seats in special compartments for which special rates are charged is abolished.

Luggage.

Clause 5. — By an alteration to the precription of clause 44 of the regulations :

The Minister of Public Works can, as an exceptional measure, authorise the railways to reduce, on services replacing the railway services, the amount of free luggage allowed each passenger to less than 30 kgr. (66 lb.), the conditions governing accompanied luggage being given in the published rates.

Bulky objects.

Clause 6. — By an alteration to clause 46 of the regulations, the railways cannot refuse to convey bulky objects which their rolling stock can carry.

In each case, they fix the conditions and transit times for large objects weighing more than 5 tons. The rates proposed can be applied if the Minister has not raised any objection after fifteen days; for at least three months the same conditions must be given to all who apply for them.

Regulations concerning consigments.
Receipts.

Clause 7. — By an alteration to clause 49 of the regulations :

1. The obligation to forward consignments for the same destination in the order they were booked only applies to goods carried under the same rate conditions, not requiring special rolling stock, which the railway is not obliged to own in sufficient quantity to meet immediately all demands.

The Minister of Public Works will determine, in accordance with the proposals put before him by the railways, the types of stock to be considered as special.

2. The receipt specified in the last para-

graph of clause 49 may not be sent until after 24 hours of the consignment being booked.

In this case, a provisional notice is got out when the consignment is booked, under the conditions to be fixed by the Minister of Public Works, as proposed by the railways.

Clause 8. — Derogations to clause 50 of the concession deed :

Despatching and transit times for railway services.

Fast goods. — The Minister of Public Works fixes at the suggestion of the railways the fast trains on which livestock, raw materials, goods and all other consignments must be carried. The proposals of the railways come into force after a period of fifteen days, if the Minister has not raised any objection within that period.

The goods are sent by the first of the booked trains going to the destination in question, provided that the consignment was handed over at least two hours before its departure.

Slow goods. — The livestock, raw materials goods and consignments of all kinds sent by slow goods trains are despatched the day after they were received at the station; this time can be increased by the number of days needed to provide special stock as defined under the conditions given in clause 7 of the present decree.

The maximum transit time by railway may not exceed 24 hours per 200 km. (124 miles) or fraction thereof.

Single class of speed. — The Minister of Public Works can, at the suggestion of the railways, set up a single class of speed which will take the place as regards rates, transit times, and other conditions, of fast and slow goods, as well as, if need be, the class provided for in clause 47 of the regulations for all or part of the goods in question.

The rates, transit times, and conditions of this class of speed are fixed in accordance with the decree of the 30th December, 1933.

Transit times for services replacing railway services.

The Minister of Public Works will fix, in accordance with the proposals of the railways, the transit times applicable to services replacing railway services.

The railways' proposals are included in the substitution proposals provided for in the last paragraph of clause 1 of the present decree.

The modifications in transit times applicable to services replacing railway services already in operation will come into force after fifteen days, if the Minister has raised no objection within this period.

Suspension of transit times.

Exceptionally, transit times cease to be obligatory for the railways under the conditions provided for in the following paragraph, when through an interruption in the working of some other method of transport, the quantity of goods to be sent by rail exceeds its normal capacity.

The Minister of Public Works determines, at the suggestion of the railways, the lines on which the transit times are to be suspended as well as the time such suspension shall apply. He extends these times, if need be.

Special regulations concerning railcars.

Clause 9. — By a modification of clauses 42, 44, 46, 49 and 50 of the regulations, the following prescriptions can be applied when the railways work rail motor cars over their lines, either instead of existing trains, or in addition to such trains.

1. The Minister of Public Works can authorise the railways to reduce the amount of luggage allowed per passenger on certain rail motor car services under the conditions laid down in clause 5 above;

2. The railways must take the necessary steps to meet all expected traffic demands and provide stock to suit. The Minister of Public Works can, as a condition for working rail motor coach services, prescribe the measures to be taken in this connection.

The obligation to carry goods and luggage is limited by the nature, dimensions and tonnage of the goods the stock in service can transport;

3. At certain stopping places without permanent staff, the Minister of Public Works

can, at the suggestion of the railways, limit the classes of the tickets issued;

4. The Minister of Public Works fixes, on the submission of the railways, the rail motor coaches and goods trains by which parcels traffic is to be worked.

Modifications to measures taken in conformity with paragraphs 3 and 4 above, suggested by the railways after the services are in operation, will come into force after fifteen days if the Minister has not raised any objection in the meantime.

PART II.

ALTERATIONS TO THE LEGAL PRESCRIPTIONS AS TO ORDER AND SAFETY ON THE RAILWAYS.

Fences and gates.

Clause 10. — By a modification to the prescriptions contained in clause 4 of the law of the 15th July, 1845, and the law of the 26th March, 1897, authorising exceptions to the said clause, the Minister of Public Works can, at the suggestion of the railways, authorise the suppression of fences alongside the railway; he can also autorise the suppression of gates at level crossings with the reserve that suitable measures be taken to assure safety of operation and safety for the public.

The demands of the railways will be investigated in the manner laid down by the Minister.

Distances.

Clause 11. — By an alteration to clause 9 of the law of the 15th July, 1845, authority to construct or maintain buildings, make excavations, or set up depots nearer the railway than allowed by clauses 5, 6, 7 and 8 of the law can be granted by the Minister of Public Works after taking the views of the railways.

PART III.

ALTERATIONS TO THE CONVENTION OF 1883 AS REGARDS THE MINIMUM NUMBER OF TRAINS TO BE RUN DAILY IN EACH DIRECTION.

Clause 12. — By an alteration to the requirements of the convention of 1883, the Minister of Public Works can authorise the railways to run, on certain lines or sections of line, fewer trains than the minimum fixed by the said convention.

Clause 13. — The Minister of Public Works is responsible for carrying out the present decree which will be published in the *Official Journal* of the French Republic.

APPENDIX C.

Decree of the 19th April, 1934, dealing with co-ordination between railway and road transport.

Clause 1. — In order to reduce the financial burden of the State, a committee has been set up at the Ministry of Public Works, to co-ordinate railway and road transport.

Clause 2. — This committee, known as the « Co-ordination Committee » is composed of :

An expert nominated by the management committee of the main line railways;

An expert nominated by the professional organisations of the light railways;

An expert nominated by the professional organisations of road hauliers holding concessions from the State, départements, or communes;

Two experts nominated by the professional organisations of road hauliers not holding State, provincial, or communal concessions.

The Minister of Public Works will draw up a list of the organisations concerned, who are to make these nominations; if they cannot come to any agreement among themselves he will make the nominations himself.

An arbitrator, nominated unanimously by the five experts and approved by the Minister of Public Works. If the experts cannot agree the Minister of Public Works will nominate the arbitrator himself.

The experts and the arbitrator are nominated for a term of three years. After that they can be re-elected.

Clause 3. — The co-ordination committee will endeavour to make departmental and regional agreements between all the transporters concerned with organising public passenger and goods services by railway and road, including long-distance transport.

If no agreement can be arrived at, the arbitrator shall submit to the Minister of Public

Works proposals for the maintenance or modification of the existing services, for the suppression of certain of them after a time decided separately for each particular case, and the setting up of new services.

The agreements or proposals shall come into force when approved, by decree, by the Minister of Public Works.

The composition and functions of the co-ordination committee may be extended or modified by decree.

Clause 4. — The ministerial decrees sanctioning the agreements or proposals of the arbitrator shall specify the conditions which road transporters must satisfy for the services in question.

These conditions deal with, in particular, the timetables and rates, the obligation to operate the service, and to treat all users equally, and to carry the mails. The decrees will fix in addition the period of validity of the agreements or approved schemes.

Clause 5. — After the publication of the present decree, until the drawing up of the ministerial decrees provided for in clauses 3 and 4, no public transport service may be set up.

In the districts where these decrees are applicable no new services can be started without the authorisation of the Minister of Public Works, which can only be given after the co-ordination committee has examined the question and the arbitrator decided in its favour.

Clause 6. — Within a period of 15 days after the publication of the present decree, all operators of public transport services not holding a contract with the State, Départements, or Communes, must send in a statement of their services to the Prefecture of the Département in which their main centre lies. This statement, the terms of which shall be fixed by a decree of the Minister of Public Works, must show to what professional group or groups of public transporters the operator in question is affiliated.

Clause 7. — Under the present decree all services for the commercial transportation of passengers or goods shall be considered as public transport services.

Clause 8. — As an exception to clause 7, exceptional passenger transport services, i. e. special services to meet traffic needs not of regular occurrence, are not affected by the present decree.

Clause 9. — All disputes or claims relating to the application of clauses 7 and 8 of the present decree shall be settled by the Minister of Public Works, after investigation by the co-ordination committee and after the arbitrator has given his opinion.

Clause 10. — Infringement of the clauses of the present decree, of the public administrative regulations laid down in the following clause, and of decrees made for carrying them out, shall be punishable by a fine of 16 to 200 fr. per infringement proved.

In addition, any infringement of the provisions of clause 5 of the present decree is punishable, should the offence be repeated, by the withdrawal, for a period of 3 months to one year, of the license to run, provided for by clause 8 of the decree of the 31st December, 1922, for all vehicles of the guilty party.

Clause 11. — All additional measures to assure co-ordination between railway and road transport will be the subject of regulations issued by the public administration.

Clause 12. — The present decree will be submitted to ratification by Parliament before the 31st October, 1934.

Clause 13. — The Prime Minister, the Ministers of Finance, Public Works, Interior, and Justice, are each responsible for carrying out the present decree, in so far as it concerns them.

APPENDIX D.

Decree of the 15th May, 1934 relating to the co-ordination of railway and waterway transport.

Clause 1. — In order to reduce the financial burden of the State, a committee has been set up at the Ministry of Public Works to co-ordinate railway and waterway transport, which is composed of :

1. An expert nominated by the Management Committee of the Main Line Railways;
2. An expert nominated by the professional organisations of inland waterway operators;

3. An arbitrator appointed by the two experts and approved by the Minister of Public Works. If the experts cannot agree, the Minister of Public Works will nominate the arbitrator himself.

The central committee is assisted by regional committees.

Clause 2. — The regional committees draw up agreements between water transport and railways, particularly with the object of reserving to the former the transport of goods carried by complete boat loads, and in particular of bulky goods.

If no agreement can be arrived at, the central committee suggests measures assuring a suitable division of the traffic between the waterways and railways, and puts these before the Minister of Public Works.

Clause 3. — The transport of miscellaneous goods, as well as the utilisation by a third party of boats belonging to industrialists or traders not engaged in transport work before the publication of the present decree, must first of all obtain an authorisation from the Minister of Public Works.

Clause 4. — After the publication of the present decree, the registration of new boats for inland navigation which could be used for the transport of goods must first of all be authorised by the Minister of Public Works.

Clause 5. — Infringement of the clauses of the present decree, of the public administrative regulations, and of the instructions issued for carrying them out, shall be punishable by a fine of 16 to 200 francs per infringement proved, and 200 to 1 000 francs should the offence be repeated.

Clause 6. — A public administrative regulation, framed according to the report of the Minister of Public Works, will lay down the measures for applying the present decree, and in particular :

1. The composition and duties of the regional committees;

2. The conditions under which the authorisations provided for in clauses 3 and 4 shall be granted.

This regulation can modify the composition or extend the powers of the central committee and prescribe all supplementary measures likely to assure the co-ordination of railway and water transport.

Clause 7. — The present decree shall be submitted for ratification to Parliament in conformity with the prescriptions of clause 36 of the law of the 28th February, 1934.

Clause 8. — The Lord Privy Seal, the Minister of Justice, the Minister of Public Works and the Minister of Finance are responsible for carrying out the present decree in so far as it concerns each of them. It will be published in the *Official Journal.*

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JAPAN.

The geographical conditions favour coastal shipping. There are numerous ports all round the country. The industries have developed near the ports, and the regions in which the raw materials and fuel are produced are not far away, so that much of the traffic is carried by boat and transport by railway is only for short distances.

In spite of this, in order to protect their traffic from competing methods of transport, the Japanese Government Railways have drawn up special rates, the essential conditions of which are as follows :

a) indication of departure and destination stations ;

b) specification of the period of the transport, for example 6 months or a year, and the tonnage to be transported during the period in question;

c) rebates granted when the tonnage reaches the specified amount.

The amount of the rebates varies with the rates and the extent of the competition.

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ARGENTINE REPUBLIC.

The information we give below is taken from a communication from the *Buenos Aires and Pacific Railway.*

a) Measures of a general nature.

Although the problem of organising the different methods of transport has not yet been solved, it is certain that the gravity of the situation has been appreciated and that efforts are being made to remedy it. The executive authorities submitted to Congress, in 1932, a draft bill proposing to put all road transport undertakings under Government control. The road operators will have to submit their rates to the administration under which the railways come ; they will also have to conform to regulations similar to those binding the railways, including in particular clauses dealing with rates of pay and working conditions. The dominant idea is to regulate the activities of road transport undertakings so as to put them on the same footing as other competitive transport undertakings already under Government control.

While the question is thus before the Legislature, the Government, after being petitioned to do so many times by the railway companies, has, by the decree of the 13th April, 1934, nominated a special Commission to study the conditions under which the transport industry functions and the economic situation of the railways, and to suggest on the basis of the results of its investigations, the administrative and legislative measures best suited to the general interests of the country.

b) Measures taken by the railway.

The amount of traffic on the suburban section of Buenos Aires being insufficient to justify the cost of electrification, close attention has been given to another method of traction to meet the very serious road competition. A month's trials with a Diesel-electric train have shown that very considerable savings could be effected in this way.

Investigations have also been made into the possibility of replacing steam traction on suburban services by light railcars with trailers, at frequent intervals, with moderate fares.

On the main line, the passenger and goods services have been speeded up.

On branch lines, rail omnibuses have been put into service and have made it possible to run a more frequent service, thereby increasing the passenger traffic. A rail motor coach with hydraulic transmission designed for a speed of 100 km. (62 miles) an hour has been ordered from England.

It is hoped, in this way, to offer the public more frequent trains on the branch lines, greater comfort, higher speed, and what is more important, reduced rates.

Rail lorries have been used for parcels traffic and also for carrying milk over sections of line where the usual service was not satisfactory. Reduced rates have been granted.

A luxury excursion train has been introduced with Pullmann coaches, sleeping cars, cars with bathrooms, a hair-dressing saloon, reading room, radio and orchestra.

Excursions are run periodically between Buenos Aires and the important towns; passengers can buy combined rail and hotel tickets for various holiday and health resorts.

As far as operating road services is concerned, the railway has made agreements with a Transport Company in the case of both passenger and goods services. The Company acts as agent for the railway in grouping consignments, which gives customers the double advantage of large tonnage rates, and door to door services.

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INDIAN EMPIRE.

North Western Railway.

a) Passenger traffic.

The road has taken traffic away from the railway to an extent equivalent to a loss of 6 % of the receipts.

Lower rates have been granted on the sections where competition is heavy, usually in the form of return tickets at reduced rates.

The fresh fruit traffic has been safeguarded by granting reduced rates, which are sometimes lower than the rates for ordinary goods.

In addition, reduced rates for complete wagon loads have been introduced in order to stimulate the fruit traffic towards the large centres.

b) Goods traffic.

Here again reduced rates have been granted. The rates are equal to or lower than those of the competitor, and their effect is being closely watched.

Competitive rates are so granted as not to cause any loss on the traffic already carried by rail, and so as to keep the receipts per wagon-mile above the average cost of transport.

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Bengal-Nagpur Railway.

a) Motor omnibus competition.

This has been felt on certain sections, especially in the case of 3rd-class passenger traffic.

The measures taken are :

1) the reduction of the 3rd-class fares between the stations most affected ;

2) the issue of 3rd-class return tickets at reduced rates, valid for short periods;

3) the running of additional light trains or steam rail coaches over sections with sufficient traffic to justify this.

The law does not allow the railways to run bus services except to connect up with railway services, but it is proposed to alter this in order to allow the railways to organise supplementary road transport services.

b) Goods traffic by road vehicles.

This competition is severe at periods when work ceases in the fields and the farmers have their vehicles idle ; the present crisis obliges them to accept very low rates. Reduced rates applied between the stations affected are the only means of bringing back the traffic to the railway.

c) Competition from coastal shipping.

The Bengal Nagpur Railway runs along the sea coast for 550 miles and serves a certain number of ports of varying importance. The traffic is threatened by coasting vessels. In the same way, there is heavy competition from water transport in the case of traffic between Calcutta and Bombay.

The railway has to keep within the terms of the law as regards minimum rates, an obligation not falling on the shipping services. The only remedy is to offer the best possible service ; express goods trains have been introduced between the ports, and very reduced rates are granted.

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AFRICA

Kenya and Uganda Railways and Harbours.

This Railway states that road competition is not very noticeable. The cause of this is that the commercial road transport of goods is not allowed in the areas served by the railway.

[625. 143.2 (.73)]

The steel rail specification of the American Railway Engineering Association,

by Cecil J. ALLEN, M. Inst. T.

(The Railway Engineer.)

Last year a new standard specification for rails manufactured from open-hearth steel, which had been approved by the American Railway Association, was adopted and put in force by the American Railway Engineering Association. In practically all respects, other than chemical composition, the new specification is identical with the previous standard, dated 1925, but, as many of the provisions in regard to tests go considerably further than the testing normally carried out on rails in this country, and have their bearing on the standard American practice of classifying the rails into grades, the details of this specification are worth description.

Analysis.

The specified composition of the steel varies according to the weight of the rail section, and must be within the following limits :

Constituents.	Weight of rail in pounds per yard.			
	70-84.	85-100.	101-120.	121-140.
	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	0.53-0.70	0.64-0.77	0.67-0.80	0.69-0.82
Manganese	0.60-0.90	0.60-0.90	0.70-1.00	0.70-1.00
Silicon	0.10-0.23	0.10-0.23	0.10-0.23	0.10-0.23
Phosphorus not to exceed	0.04	0.04	0.04	0.04

In the previous specification carbon was identical in the 70-84 lb. range, but varied from 0.62-0.77 % in the 85-100 lb. range, was permitted up to 0.83 % in the 101-120 lb. range, and was from 0.72 to 0.89 %, instead of the revised 0.69 to 0.82 % of the new specification, in the 121-140 lb. range. Manganese remains unchanged at 0.60-0.90 % up to 100 lb. per yard, but above that weight of rail is increased from the previous limits of 0.50-0.90 % to new limits of 0.70 to 1.00 %.

It is surprising, in view of the experience now available as to the enhanced wearing capacity of rails whose manganese content has been increased above the 1.00 % limit, that American engineers still determine to limit the manganese percentage to a maximum of 0.90 % in their lighter rails and 1.00 % in their heavier, and all in order to permit the retention of very high percentages of carbon, which have probably been more responsible than any other cause for the widespread menace in America of the transverse fissure in rails. In Great Britain the specifications of the four leading railways now call for from 0.90 to 1.10 % manganese, in association, in the open-hearth basic process, with from 0.50 to 0.60 % carbon, except in the case of the Great Western Railway, which works between carbon limits of 0.45 and 0.55 per cent. One reason for the extremely high American carbon percentages is doubtless to give added resistance to deformation of the rails in the vertical plane, as a result of axle-loads which exceed the maximum permitted in this country by over 50 %; but in addition to the risk of fissure failures so entailed, experience in this country points clearly to the conclusion that such carbon increases progressively reduce the capacity of the rails to withstand abrasive wear. Higher carbon results in greater hardness, but does not provide the toughness which is needed as a resistant to abrasion; and it is here that manganese is proving its worth, even accompanied, as are the increased manganese percentages of this country, by a reduction in carbon. It should be emphasised here, however, that just as in Great Britain all the railways have now broken away from the B.S. specification in regard to rail steel analysis, so various American railways are to-day using medium manganese rails, though with far higher combined percentages of carbon and manganese than would be tolerated here.

As regards other elements, the American specification continues necessarily to limit phosphorus to a maximum of 0.04 %, as at anything above this figure the rails would probably be dangerously brittle; in the higher manganese British rail specifications it has now been found possible to relax the phosphorus maximum to 0.05 %, and even on the London & North Eastern Railway to 0.06 %, in view of the lower carbon content. Phosphorus, within safe limits, is a valuable wear resistant, so that here also the recent British modifications are likely to be to the advantage of the rail. Silicon, of which in the previous American specification a minimum of 0.15 % was demanded, is now limited to a maximum of 0.23 %, while the minimum is lowered to 0.10 %. The latter figure corresponds with British practice, which calls for between 0.10 and 0.30 % silicon, though it is but seldom that anything more than 0.20 % is actually supplied. No sulphur limit figures in the American specification, as in the British, and none is necessary, as the rail manufacturer, in his own interest, will avoid excessively high sulphur percentages, owing to the trouble that they are likely to cause him with red shortness of the metal during rolling.

The American specification asks that the average carbon content of the whole of each rolling shall be roughly equal to the mean of the carbon limits for that weight of rail, and that there shall be as many casts with carbon above the mean as there are below it. Special marking is adopted in the case of all rails rolled from casts whose carbon percentages fall within the uppermost 5 points of the carbon range for that weight of rail. For verification of the analysis to the user, the American specification requires that small test ingots shall be cast at the same time as the second and one of the last full ingots of each heat; carbon and manganese determinations shall be made separately in each case; and from equally mixed drillings from each pair of test ingots so cast, determinations of silicon, sulphur, and phosphorus shall be made to represent the heat. As a further check, doubtless to verify absence of segregation, once in every ten heats or casts the manufacturer is required to take drillings from both the centre and the outside of the head of a rail rolled from the top end of the last ingot of the heat — that is, in the worst possible conditions relatively to both the cast and the ingot.

Branding.

In the rolling of the American rails, marking is adopted which enables any finished rail to be related, not only to the cast or heat, but also to the particular ingot and the position in the ingot from which it has been rolled. In sequence there are hot-stamped on the web of the rail, in a position which will not be obscured by the fishplates when the rail is laid in the road, the cast number, then a letter (« A » for the top of the ingot, and then « B », « C », « D », etc., down to the bottom of the ingot), and, last, the number of the ingot in the sequence of casting from that heat. These indications are in letters 5/8 inch deep, and are additional, of course, to the normal branding rolled on the web, showing the weight and type of section, steel process, manufacturer, and month and year of manufacture. The former special branding is of considerable importance in relation to the testing and subsequent classification of the rails. If the amount of discard cut from any ingot should, for any special reason, be equivalent in quantity to the length of a rail, then the « A » rail is omitted, and the sequence is permitted to begin at « B ». Any rail which appears on the inspection benches without having received this branding while hot can be accepted only as a rail in the « No. 2 » category, described later.

Tests.

In its severity the falling weight test imposed on American rails is considerably inferior, weight for weight of section, to the British test. The weight of tup in the former is 2 000 lb.; the supports 3 feet apart (except in the case of rails of 106 lb. per yard and over, when they are 4 feet apart), and the heights of fall are as follow :

For 81-90 lb. rail, inclusive . . .	18 feet.
For 91-100 lb. rail, inclusive . . .	19 feet.
For 100-120 lb. rail, inclusive . . .	20 feet.
For 121-140 lb. rail, inclusive . . .	22 feet.

By comparison, the height of fall in the B.S.I. rail specification, for a rail of 100 lb. per yard flat-bottomed section, on 3 ft. 6 in. supports — 6 inches wider apart than in the American test — and with a 2 240-lb. tup, is 22 ft. 6 in. as against 19 feet. In every respect the British test is thus the more severe of the two; on the other hand, with the percentages of carbon worked to in the American specification, it would be difficult for the American rails to sustain the British test without fracture.

In American practice tests are cut from the second, the middle, and the last full ingots of each cast. The B.S.I. specification calls for a second falling weight test from any cast only if there is more than 50 tons of steel in the cast; and the use of the top-end crop from the ingot for testing is subject to the agreement of the manufacturer. If one of the three American tests fails, all « A » rails from that cast are rejected, and additional tests are cut from the bottom end of the same « A » rails, or the top of « B » rails from the same ingots. Should any of these fail, the « B » rails are rejected, and tests are cut from « C » rails. Failure of any « C » rail test entails rejection of the whole cast. This method has, from the manufacturer's standpoint, an advantage over the British method, which calls for two re-tests in the event of breakage of the original test, and if one of the re-tests breaks — making two failures out of three tests — the whole cast is liable to rejection, whereas the American method may save all the rails from below the « B » or « C » position in the ingot. But the operation of the latter is obviously subject to the branding of the rails in the manner described.

In the American specification, the permanent set of each test-piece is measured on a length of 3 feet after the first blow, but for information only. In British practice, however, a maximum permissible deflection is specified. One of the three test-pieces from each American cast is tested to destruction by repeated blows from the falling weight, and the final deflection is measured, also for information only. The remaining two test-pieces are then nicked and broken, and the fractures of all three are examined. It is laid down that « if the fracture on any test specimen exhibits seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine-grained structure », all the « A » rails (from the top of the ingot) in that cast shall be separately classified, and described as « X-Rayls ». There would appear to be room for considerable argument here as to what actually constitutes a « distinctly bright or fine-grained structure ».

As to other tests, for information only one of the three test specimens is tested by Brinell indentation on the head of the rail, through the medium of a ball of 19 mm. diameter under a weight of 100 000 lb. No tensile test is taken, as in British practice, for it is doubtless considered that the exhausted ductility development of the falling weight test, in conjunction with the Brinell test, are together sufficient to supply corresponding information.

Manufacture.

The standard length of American rails is now fixed at 39 feet, and 11 % of each order is accepted in shorter lengths varying in even feet from 38 feet down to 25 feet. This compares with the percentage of only 7 1/2 % in short length rails on British contracts for 60-foot rails. The purpose of such percentages is to utilise, either as closures or for switch and crossing purposes, lengths of rail which would otherwise be waste owing to their being shorter than the standard length. It is generally customary to allow the manufacturers to cut the end off any rail which is found to be defective at one end only, and to accept the remainder as one of these shorter rails; in the American specification a rail so cut back is classified in the « X-Rayl » group. But the inference from this higher American percentage of 11 on the total contract quantity, accepted in shorter than the standard lengths, is that the proportion of rails defective at the ends is larger than in this country, especially also as the British standard length is so much greater than the American. On the American standard length of rail a tolerance of 3/8 inch long or short is permitted, and on 15 % of the order an even greater tolerance of 7/16 inch is permitted. This is chiefly because the American rail is accepted as cut by the hot-saw, with no further attention than the removal of the burrs; in Great Britain, however, it is now the general custom to plane both ends of each rail (making much easier than with unplaned ends the detection of piping defects), and to demand that even 60-foot rails shall not vary in length by more than 3/16 inch up or down. As regards other manufacturing details, the height of the section is permitted to vary to the extent of 1/64 inch below or 1/32 inch above the drawing figure, and the width of the flange up to 1/16 inch above or below (no corresponding tolerance is given in British Standard rail specification); but, as in the B.S.I. specification, the weight tolerance is 1/2 % above or below the calculated weight of the section. The American rail inspector is also authorised to accept rails with slight skin defects, of such a description as will not, in his judgment, seriously affect the life of the rail; such rails, however, are classed as « No. 2 » instead of « No. 1 » rails, and will be accepted up to 8 % of the total contract quantity.

Classification markings.

A complex system of classifying the rails is in force in America, the various classifications being indicated by painting the rail-ends in the manner described below.

1. *Unpainted.* — « No. 1 » quality rails, all of standard length, have their ends unpainted and unmarked. For reasons already given, they are not likely to exceed 60 to 65 % of the total contract quantity.

2. *Blue ends.* — Special provision is made for indicating rails of « No. 1 » quality whose carbon content is within the uppermost 5 points of the specified carbon percentage. Such rails are painted with blue ends.

3. *Green ends.* — These are rails of « No. 1 » quality, but shorter than the standard 39-foot, length.

4. *Yellow ends.* — Yellow paint is used to indicate the top rail of every ingot, which is in all other respects of « No. 1 » classification.

5. *Brown ends.* — For the « X-Rayl » classification, to which detailed reference has been made, brown paint is used, and in addition the letter « X » is stamped on both ends.

6. *White ends.* — White paint is used to indicate rails of « No. 2 » quality, which also must have the figure « 2 » stamped on both ends. In this category are rails accepted as slightly defective, and also rails which arrived at the straightening presses either sharply kinked, or with a camber of more than 6 inches in their length of 39 feet, so that excessive straightening was necessary.

While, therefore, the American specification goes further than the British in certain respects, and particularly the distinctive branding by which both the portion of the ingot from which the rail has been cut, and the number of the ingot in the sequence from that cast, can be verified, it is difficult to avoid the conclusion that certain of the provisions of the American specification have been drawn up to cover a quality of rail which, in general, is inferior to that normally produced in this country. The desirability, or the reverse, of applying such provisions to British rail manufacture is governed entirely by whether or not the extra labour and expense imposed on the manufacturer by their application would be justified by an improvement in the quality of the rail which might be so secured. Experience of the freedom of the British rail from defects, to which an article in the November, 1933, issue of *The Railway Engineer* (1) bore striking testimony — in comparison with the relative frequency of rail defects in other countries — suggests that the general provisions of the British Standard Specification in regard to rail manufacture (apart from the analysis, which still fails to recognise the medium manganese quality of rail now standard in this country, and, possibly, undue severity in the falling-weight test) and inspection in this country are sufficient to ensure the supply to the user of rails of satisfactory quality.

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(1) See *Bulletin of the Railway Congress*, April 1934.

[624. 7 (.71)]

Canadian National constructs another unusual concrete bridge.

(Railway Age.)

The central region of the Canadian National, which during the last few years has constructed a number of reinforced concrete railroad bridges of unusual design and proportions, has recently completed another such bridge, which, in certain respects, eclipses any similar bridge in Canada or the United States. This bridge is a two-track structure of rigid or fixed-frame construction, a design little used up to the present time for railroad loadings, which provides a clear span of 72 ft. 6 1/4 in. between abutment faces, with a slab thickness of only 3 ft. 9 in. at the center. Another unusual feature of the bridge, particular-

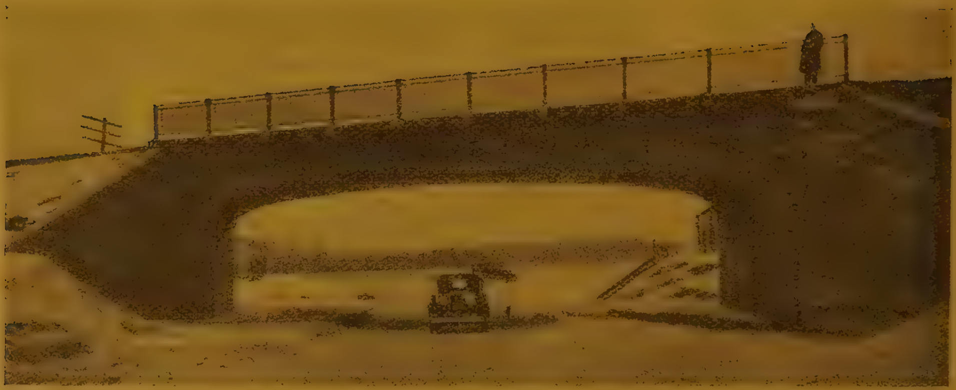


Fig 1. – The fixed-frame Petite Cote road bridge provides a clear opening of 72 ft. 6 1/4 in.

ly in view of its design, is the fact that it carries no ties or ballast, the track rails being fastened directly to the top of the deck slab and separated from it by only relatively thin oak cushion strips.

Second fixed-frame bridge on road.

The bridge in question was constructed on the main line of the St. Lawrence division of the Central region, near Vaudreuil, Quebec, about 26 miles west of Montreal, and was designed to provide an overhead crossing of a re-alined and widened section of Petite Cote road, which formerly crossed the railroad at grade approximately 100 feet further west. Since the new section of the road is an important link in a new Montreal-Ottawa highway, of such width as to require a considerable span unless a pier were permitted in the center of the roadway, consideration several years ago ran first to steel girder design. However, the experiences of the road in more recent years have so broadened the acceptance of reinforced concrete for grade separation projects that concrete construction was considered to be adapted for the bridge, in spite of the long span required, and, in the fixed-frame design, was found to be much more economical than other types of construction. In fact, the Canadian National estimates that the fixed-frame design was at least 40 % cheaper than any other type which might have been used.

The first fixed-frame bridge to be built on the Canadian National was constructed in 1932 at Toronto, Ontario. This bridge, which carries two main tracks over St. Clair avenue, is similar to the Petite Cote road bridge in several respects, but, unlike the latter bridge, the deck slab is made continuous over a center pier, resulting in two clear roadway spans of 49 feet. This bridge was described in some detail in the *Railway Age* for September 10th, 1932. Its slab thickness is only 3 ft. 9 1/4 in., and, contrary to usual practice, the track structure consists of reinforced concrete ties laid directly on the slab and filled around with concrete to keep them in true alinement.

In the fixed-frame construction used both at St. Clair avenue and Petite Cote road, the abutments and deck slab are monolithic, the ends of the slabs being designed to take negative bending moment, which is carried into the abutments by the rigid reinforced connection between the slabs and the abutments. As a result of this rigid connection, the moment at the center of the

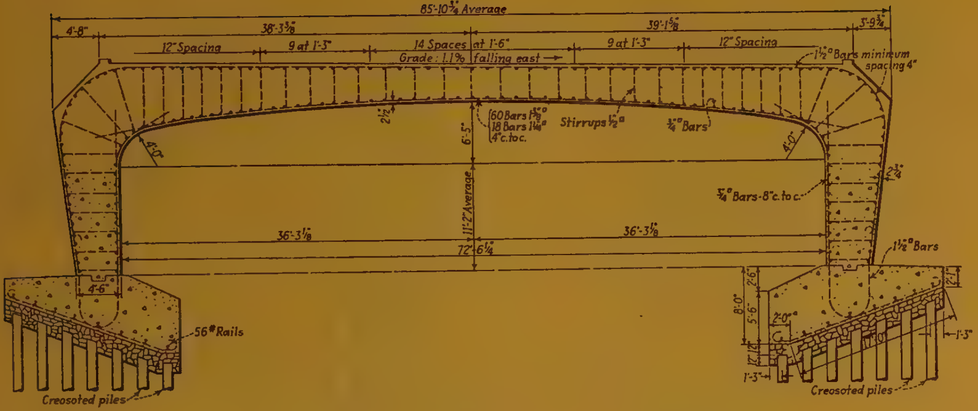


Fig. 2. — Longitudinal section through the fixed-frame bridge.

slab was reduced sufficiently to permit an appreciable reduction in the effective depth of the slab as compared with a simple span slab.

Details of bridge design.

The bridge over Petite Cote road carries two tracks on a one-degree curve and crosses the highway at an angle of 57° 30′. Since the new highway was depressed to pass beneath the railroad, no change of grade or elevation of the tracks was involved, and all of the abutment and foundation masonry for the bridge was put in an excavation made for the purpose. In order to keep one track in service at all times, the bridge, above the footings, was constructed one half at a time, each half consisting of a slab of 72 ft. 6 1/4 in. clear span, 13 feet wide, and monolithic at both ends with the abutments. A special feature of the slabs is that while the top, for all practical purposes, is flat, the underside is arched, giving a gracefully curved intrados with rather sharply curved fillets between the ends of the slab and the abutments. These fillets not only add to the appearance of the bridge, but also serve to avoid excessive stresses at the re-entrant angle where the slab and abutment join.

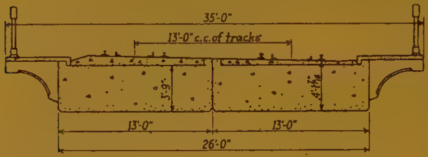
Concrete walkways provided.

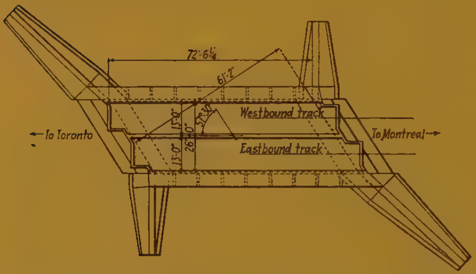
Another feature of interest in connection with the deck slab is the fact that concrete walkways are provided along both sides, these consisting of reinforced 4-inch slabs supported on a series of reinforced concrete brackets, integral with the slabs and spaced 8 1/2 feet center to center. The outer edge of each walkway is provided with an ornamental iron railing which is continuous between cast iron posts located directly above and in line with the walk-supporting brackets.

The abutments of the bridge differ radically from the usual gravity type, being essentially continuations of the slab down to keyed connections with quite massive spread footings. The inside faces of the abutment walls are vertical, but the back faces, instead of flaring outward, are battered inward from a thickness of about 8 feet at the top to 4 1/2 feet at the bottom.

The abutment footings, which were constructed continuous across the full width of the bridge, are irregularly-shaped masses in cross section, with an over-all width of 18 feet and a maximum thickness of 7 feet. The most unusual feature of these footings is that while the keyed joint between them and the abutment walls is on a horizontal plane, the base of each footing is on an incline which slopes upward 5 ft. 9 in. in a backward distance of 16 feet. This brings the plane of support of the footing normal to the calculated direction of the resultant of the forces applied to the foundation. Both footings are carried on creosoted piles driven vertically but cut off parallel to the plane of the footing bases. These piles, of which 77 were required under each footing, were placed on 2 ft.-7 in. centers. This permitted a foundation bearing calculated at 3.2 tons per sq. foot.

Typical cross-section of the Vaudreuil bridge deck.





General plan of the fixed-frame bridge over Petite Cote Road.

Fig. 3.

Reinforcing is not unusually heavy.

As might be expected, the entire fixed frame, that is, the deck slab and the abutments, is heavily reinforced. The tension reinforcement for maximum positive moment, namely, in the intrados at the crown, consists of square bars of both 1 1/4-inch and 1 3/8-inch sizes at 4 inches center to center, or 1.06 % of the effective section. As these bars vary from 30 feet to 78 feet in length, the bar spacing is increased at intervals to about 17 inches at the ends of the span. The tension reinforcement for maximum negative moment, namely in the extrados of the slab near the abutments and ex-

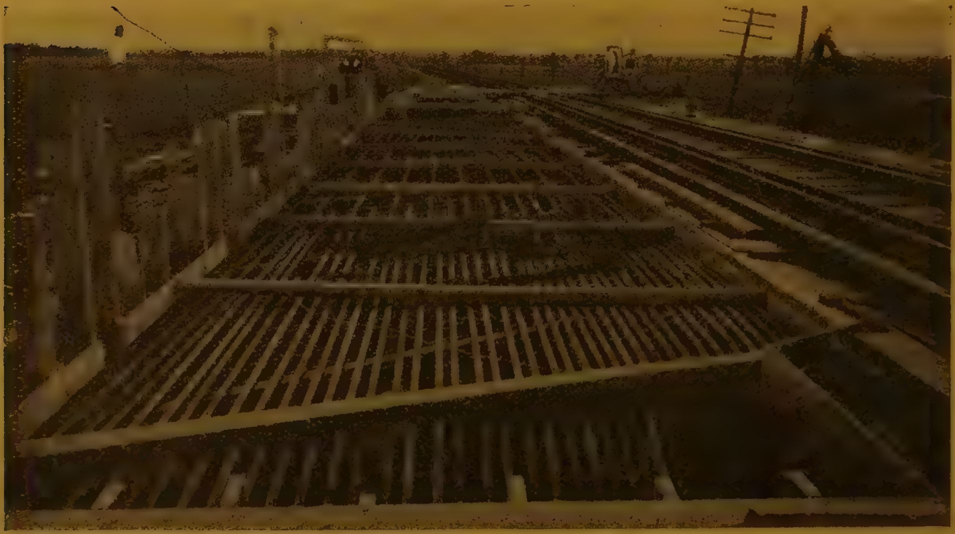


Fig. 4. — The top of frame reinforcing for half of the bridge, in place.

tending around over the backs of the abutments, consists of 1 1/2-inch square bars at 4 inches center to center, these bars also being cut off at various points approaching mid-span so that the spacing is increased to about 17 inches at the crown. The maximum percentage of extrados reinforcement is about the same as in the intrados at the crown. The vertical reinforcement in the inside face of the abutments consists of 3/4-inch square bars at an 8-inch spacing, while the lateral reinforcement in the entire structure consists of bars of the same size spaced from 12 to 18 inches center to center adjacent to the inside and outside faces. All stirrups were made from 1/2-inch square bars.

The footings were reinforced for lateral stiffness, for cantilever action of the heel and toe, and to provide the necessary connection with the abutment walls. The base reinforcing in each footing includes eight lines of old 56-lb. track-rails, laid lengthwise and spaced from 1 ft.-9 in. to 2 ft.-9 in. centers, and 1 1/8-inch square rods about 8 inches center to center, laid transverse to the rails and hooked at the ends. The abutments are tied to the footings by 1-inch square rods, 21 ft. 1 in. long, which are bent in the shape of a U, with the loops placed near the bottom of the footing at a spacing of about 8 inches.

All of the main renforcing in the frame and footings is of square deformed bars of high carbon steel with a minimum ultimate strength of 80 000 lb. per sq. inch. Altogether, there are 96 144 lb. of bar reinforcing in the frame and 12 894 lb. in the two footings, or an average of about 139 lb. per cu. yard of concrete. No spliced or welded joints were permitted in any of the bars, the specifications requiring that all bars be rolled to full length. The specifications also required that great care be exercised in placing the bars to the spacing shown and that they be securely wired together at all intersections.

No track ties or ballast employed.

Following a practice first tried on the Canadian National in 1932 on a half-through plate girder structure with a steel and concrete deck, at Breslau, Ont., the tracks over the bridge at Vaudreuil are supported on neither ties nor ballast, each rail being laid on an independent longitudinal creosoted oak cushion strip.

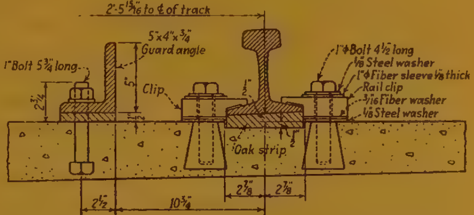


Fig. 5. — Assembly detail of rail fixtures.

Unlike the Breslau bridge construction, however, where the oak cushion strips are set directly on the deck slab, the cushion strips of the Vaudreuil bridge are laid in grooves 5 3/4 inches wide by 1/2 inch deep in a filler layer of concrete placed directly on top of the load-carrying slab. This filler layer directly beneath the tracks was provided both to simplify the matter of providing the proper superelevation of the rails for the one-degree curve of the tracks, and to insure the accurate placing of the rail fastenings. The thickness of the filler layer, which has 4-inch by 4-inch electric welded reinforcing mesh near its top face to prevent surface cracks, ranges from 7 3/4 inches on the high side of the ouside track, to 3 5/8 inches on the low side of the inside track. A 1 in 40 cant in the individual rails is provided for in the shape of the oak cushion strips.

The rails are held in place by special clips at intervals of 2 ft. 1 in. along both sides, secured to the slabs by 1-inch bolts which are turned down into internally-threaded steel sockets embedded in the concrete. Guards of 5-inch by 4-inch by

3/4-inch steel angles, with the 5-inch leg up, are provided inside each rail, 10 3/4 inches in from the center-line of the rail, and are secured in place by 1-inch bolts, 5 3/4 inches long, the heads of which are embedded in the concrete.

Bridge constructed one-half at a time.

In order to maintain operation during construction, the fixed-frame, as already stated, was constructed on the continuous footings, one-half at a time, the south half being constructed first. To permit excavation for the entire structure, as well as the driving of the pile foundations beneath the footings, both tracks were first supported on temporary pile trestlework. With this in place, the south track was taken up and that half of the bridge was completed. After the concrete in this half had cured for 18 days, all traffic was put over it, completely freeing the north side for the completion of the structure.

In the foundation work, excavation for a footing was made to neat lines down to a depth of 2 feet below the plane of the sloped bottom of the footing. The piles were then driven and were cut off one foot below the plane of the footing base. Then crushed stone was placed in the excavation and compacted thoroughly around the piles and over the pile heads to the exact elevation and slope of the base of the footing, following which the footing itself was placed.

Wooden forms were used throughout for the frame, and the concrete for each single-track half was placed in one continuous operation. Following construction of the frame, the back faces of the abutments were given two coats of asphalt emulsion, and were then carefully back-filled with rock for a distance of 15 to 20 feet in order to eliminate lateral earth pressure against the structure. To insure thorough drainage of the back-fill, six-inch transverse tile drains were provided just back of the abutments and directly along the tops of the footings, leading to a number of four-inch weep holes through the abutments at the highway level.

To waterproof the longitudinal joint between the two halves of the bridge frame, and also the joints between the frame and the wing walls, 6-inch by 1/8-inch strips of sheet lead were buried in the concrete about 2 inches below the surface.

The wing walls of the bridge are of mass design, on creosoted timber piles, and have no rigid connection with the fixed frame. To prevent bond between the frame and wing walls, strips of single-ply roll roofing were laid up in the joints when the walls were poured. Like the abutments of the fixed frame, the wing walls were provided with weep holes near their bases and were waterproofed on their back faces with two coats of asphalt emulsion. No waterproofing is applied on the deck slab, dependence against percolation through the slab and for drainage being placed in the dense concrete used and the 1.1 % grade on which the slab is constructed to correspond with the track grade.

High-strength concrete employed.

The Vaudreuil bridge was designed for Cooper's E-60 loading, using the impact formula $\frac{L^2}{L+D}$ and assuming the live load on each track to be spread over 13 feet, the full width of each slab. Specifications for the concrete used in the bridge called for 3 000-lb. concrete at 7 days in the entire fixed frame structure and its footings, and for 2 000-lb. concrete at 28 days in the wing walls. They also provided for close control of the mix in accordance with the water-cement ratio. Tests of cylinders made during construction insured a thorough check of the strength obtained. All exposed faces of the abutments, wing walls and deck slabs were paneled for appearance, and all exposed edges were chamfered for appearance as well as to prevent possible breaking off. Without any special treatment, the exposed faces of the concrete were found to be of good appearance, although some special surface treatment may be applied in the spring to remove such form marks as appear. Altogether, 1 383 cu. yards of concrete were employed in the structure, consisting of 786 cu. yards of the 3 000-lb. class and 597 cu. yards of the 2 000-lb. class.

Throughout the entire construction every precaution was taken to insure that the materials and workmanship employed were in accordance with the plans and specifications. A qualified inspector was maintained on the job at all times, and engineering supervision was a matter of daily occurrence. The Canadian Inspection and Testing Company, Ltd., had charge of the mill and field inspection of all materials, and also the testing of all concrete cylinders.

In the fixed-frame design of bridge, such as was constructed at Vaudreuil, and especially with the track rails fixed directly to the deck slab, the Central region of the Canadian National believes that it has an ideal bridge structure for many grade separation projects. It is pointed out that the design is pleasing in appearance, economical and relatively simple to construct, and that through the shallow deck slab and absence of ties and ballast, underclearance of any specific amount can be secured with a minimum amount of grading, either when raising the tracks or lowering a street or highway. In addition, it is expected that the structures will require a minimum of maintenance.

The decision to use the rigid-frame span at the Vaudreuil crossing was made by C. B. Brown, chief engineer of the Canadian National Railway System, at Montreal, the bridge being designed by the bridge department of the Central region of the road at Toronto under the direction of C. P. Disney, bridge engineer, T. T. Irving, chief engineer, and W. A. Kingsland, general manager.

[621. 132.5 (.44)]

Paris-Lyons and Mediterranean Railway Company's new 2-10-2 (class 151.A) goods locomotives developing 3000 drawbar horse power, (1)

by A. PARMANTIER,

Assistant Chief Mechanical Engineer, Paris-Lyons & Mediterranean Railway.

(*Revue Générale des Chemins de fer.*)

I. — Foreword.

The new class 151.A locomotives are compound superheated engines with five pairs of coupled wheels 1.500 m. (4 ft. 11 in.) in diameter with a leading and trailing truck. They are fitted with feed water heaters.

The boiler, except in a few details, is the same as the one used on the more

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(1) A preliminary article on this type of locomotive was published in the August, 1933, issue of the *Bulletin*, page 722.

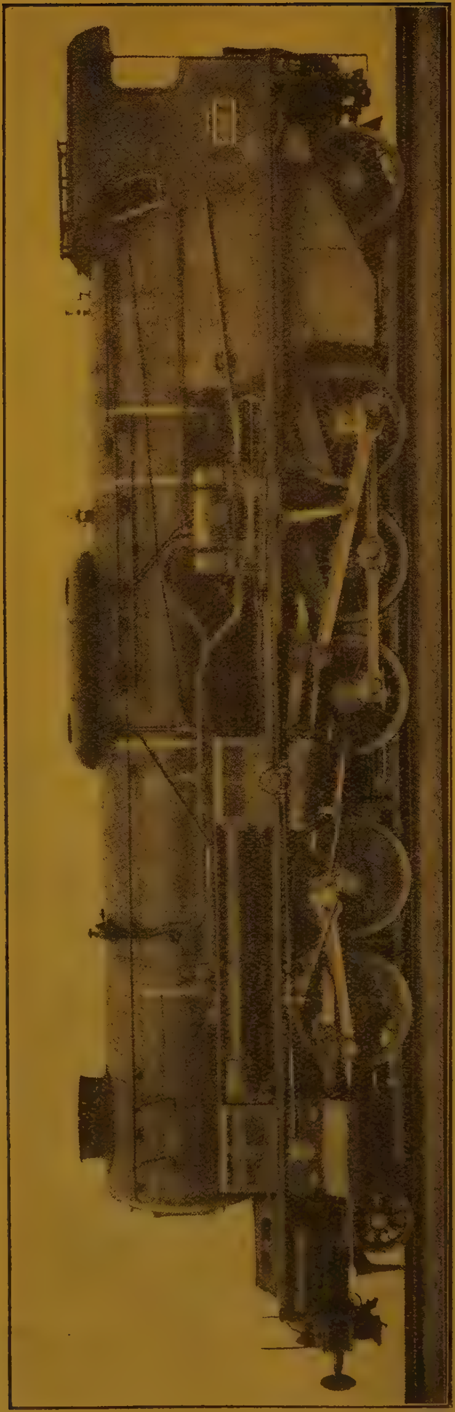


Fig. 1. — P.L.M. class 151-A goods locomotive.

recent *Mountain* type engines (²) of the P.L.M. and has 5 m² (53.8 sq. feet) grate area and a boiler pressure of 20 kgr./cm² (285 lb. per sq. inch).

It is fitted with the *Dabeg rotary cam poppet valve gear.*

The most interesting, and novel, feature of these engines, is that *the four cylinders are all located outside the frames.* The following is the reason for this layout.

The high-pressure cylinders would have had to be fitted between the frames as the low-pressure cylinders, 745 mm. (39 5/16 inches) diameter, are too great to go in. The crank axle would have had to transmit 2 000 H.P. continuously, and experience has shown that crank axles are not always able safely to withstand such loads. In order to avoid this drawback, the high-pressure cylinders were, like the low-pressure, placed outside the frames.

The high-pressure cylinders are located about the middle of the engine and drive the sixth pair of wheels. The low-pressure cylinders are at the leading end and drive the third pair of wheels.

The high-pressure group consists of the fourth, fifth and sixth pair of wheels, and the low-pressure group of the second and third pairs. The two groups are coupled together by two inside coupling rods with their crank pins at 90° on the third and fourth axles.

The 151.A class locomotives can run round curves of 140 m. (7 chains) radius on 1.45-m. (4 ft. 9 in.) gauge track; they weigh 122.4 t. (120.5 Engl. tons) in normal working order (without tender), and 185 t. (182 Engl. tons) (wih a tender carrying 28 m³ = 6 160 Br. gallons of water). The maximum speed for which they are intended is 85 km. (52.8 miles) an hour.

(²) Cf. *Revue Générale*, September, 1932, issue. The 241.C-1 express locomotive of the P.L.M. Company, by A. Parmantier.

II. — Description of the 151.A locomotives (figs. 1 to 10).

1. The boiler.

The boiler pressure is 20 kgr./cm² (285 lb. per sq. inch) and the grate area is 5 m² (53.8 sq. feet). The boiler is practically the same as that of the 241.C-1 locomotive described in the *Revue Générale* of September 1932.

The chief differences are the following :

The combustion chamber is 1.175 m. (3 ft. 10 9/32 in.) instead of 2 m. (6 ft. 6 3/4 in.) long.

The steam dome is placed half way along the engine in order to get over the priming experienced with the 241.C-1 locomotive with the dome at the leading end.

The boiler is fed with hot water supplied by a Dabeg type 120 B feed water heater and pump.

2. Frame.

The steel frame plates are 28 mm. (1 1/8 inches) thick, and are cross braced by the :

— H section front buffer beam carrying the buffers and couplings;

— back buffer beam built into the dragbox;

— a frame stay between the l.p. cylinders;

— a frame stay between the h.p. cylinders;

— and 8 cast-steel cross stays.

3. Trucks.

The side control of the leading truck is by links with double knife edges at the top end.

The trailing truck is the standard P.L.M. type.

4. Motion.

a) *Cylinders.*

The cylinder diameter and piston stroke are as follows :

	High-pressure.	Low-pressure.
Diameter . . .	0.480 m. (18 7/8 in.)	0.745 m. (29 5/16 in.)
Stroke	0.650 m. (25 5/8 in.)	0.700 m. (27 1/2 in.)

The ratio of the volumes of the l.p. cylinders to that of the h.p. is as 2.58 to 1.

The l.p. cylinders carried ouside the frames are horizontal and drive the second pair of coupled wheels. Owing to the large diameter of the cylinders and in order to clear the loading gauge, their centre line has had to be made 40 mm. (1 9/16 inches) above the centre line of the coupled wheels driven by them.

The high-pressure cylinders, which are also carried outside the frames, are set at an angle of 7° 7' 30" with the horizontal, and drive the fifth pair of coupled wheels.

Garex piston rod packings (labyrinth type with cast iron rings) are fitted on the h.p. piston rods and King packings (with rings made of AP³) on the l.p. rods.

b) *Steam distribution.*

The steam distribution is controlled by *poppet valves* driven by the Dabeg Company's R. C. type *rotary cam gear.*

1. *General layout* (fig. 3). — Each cylinder has two steam valves, two exhaust valves and a cam box.

The 4 valve spindles are arranged in a plane at right angles to the longitudinal plane of the engine and parallel to the centre line of the cylinders. The steam

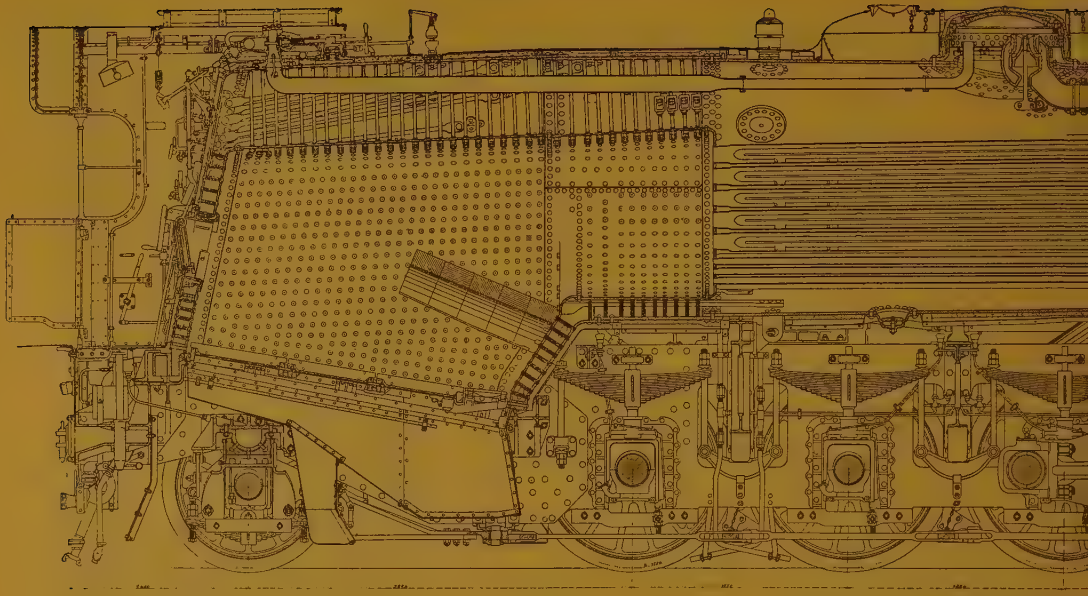


Fig. 1*a*. — Longitudinal sceti

valve spindles are on the same centre line; the exhaust valve spindles are also on the same centre line which is parallel to that of the steam valves.

2. *Poppet valves.* — The valves are double seated.

The valve spindles slide in bushes which at the same time form the valve seats. Owing to their large diameter, the exhaust valves are guided, not only by their spindles, but also by a piston free to slide in the valve cover (fig. 4).

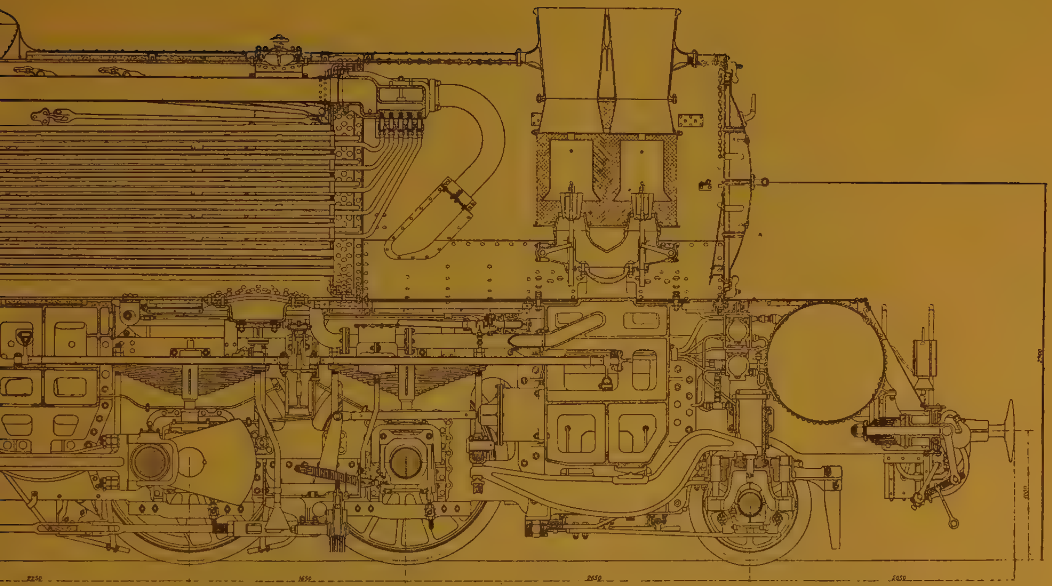
The diameters of the valves are as follows :

	High-pressure.	Low-pressure.
Steam valves	180 mm. (7 3/32 in.)	195 mm. (7 43/64 in.)
Exhaust valves.	180 mm. (7 3/32 in.)	240 mm. (9 7/16 in.)

3. *Cam boxes* (figs. 4, 5 and 6). — *Each of the four cam boxes has a cam shaft which revolves at the same speed as the driving wheels,* and a worm wheel, keyed to the cam shaft (fig. 5).

Each cam shaft has *four sets of cams,* two for admission and two for exhaust (one for fore gear and one for back gear). These cam sets have a certain number of profiles, each of which corresponds to a particular cut off; it is only possible therefore to work at the cut-offs *provided* or, in other words, *the cut-off is not continuously variable.* The cam profiles are connected together, the slope of the connecting piece being 25° A circular or « neutral cam » is provided (in each set) which, while allowing the admission valves to remain closed the whole time, keeps the exhaust valves off their seats. This position coincides with the mid gear and thus acts as a *by-pass* (fig. 6).

The cams drive rollers carried by the *intermediate levers* which operate the valve spindles through *plungers.* The valves are kept on their seats by coiled springs (fig. 4).



ne class 151-A locomotive.

4. *Rotation of the cam shafts* (fig. 7). — The cam shafts obtain their rotary motion from the second pair of coupled wheels. Each of these wheels drives, through a gear box, a shaft which rotates both the h.p. and l.p. cam sets on its side of the engine. This is done by a return crank on the crank pin of the second pair of coupled wheels, the pin of the return crank being on the same centre line as that of the axle. The return cranks carry the gear boxes, each containing a worm wheel and worm, the wheel being keyed to the return crank pin.

Their action is transmitted to the intermediate gear box and to the worms driving the cam shafts through tubular cardan shafts of the « Mechanics » type with sliding joints. As the axle gear boxes are attached to the axle, the cardan shafts and sliding joints deal with vertical and transverse movements; the boxes are prevented from turning by a guide rod secured to the h.p. cylinder.

The worms have all five threads and the worm wheels 24 teeth; the number of revolutions of the cardan shaft is therefore 4.8 times that of the coupled wheels.

5. *Reversing gear and conjugated valve gears* (fig. 3, 8 and 9). — The *cut-off* in fore or back gear is altered by sliding all the cam shafts an equal amount. The reversing gear is controlled in the cab by a *single wheel actuating* cardan shafts by means of a gear box The rotary motion so obtained is changed into a rectilinear motion by pinion and rack which, through levers and links, moves *the four cam shafts along their center line.* The movements of the h.p. and l.p. cam shafts are therefore linked together, with the result that *the h.p. and l.p. valve gears are conjugated,* as on nearly all P.L.M. locomotives.

The reversing gear is very easy to work (1).

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(1) The operating shaft makes 1/10th of a revolution for each revolution of the hand wheel.

Nine turns of the reversing wheel are required to go from full fore to full back gear.

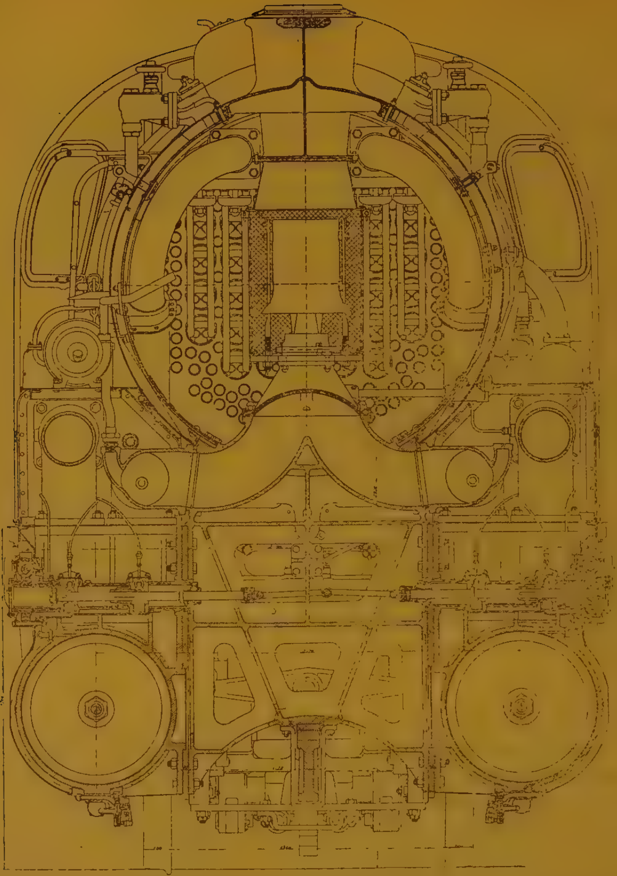

Fig. 2. — Cross section through the smokebox. Class 151-A locomotive.

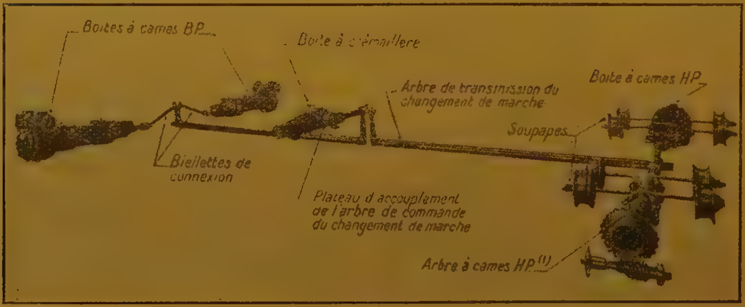
Boites à cames BP
Boite à crémaillere
Arbre de transmission du changement de marche
Boite à cames HP
Soupapes
Biellettes de connexion
Plateau d'accouplement de l'arbre de commande du changement de marche
Arbre à cames HP(1)

Fig. 3. — Poppet valve gear — general layout.

Explanation of French terms:
Boites à cames BP = Low-pressure cam boxes. — Biellettes de connexion = Connecting links. — Boite à crémaillère = Rack and pinion gear box. — Plateau d'accouplement... = Reversing shaft flexible coupling. — Arbre de transmission... = Reversing shaft. — Soupapes = Poppet valves. — Boite à cames HP = High-pressure cam box. — Arbre à cames HP (1) = High-pressure cam shaft (1).

(1) The plungers are not shown in place.

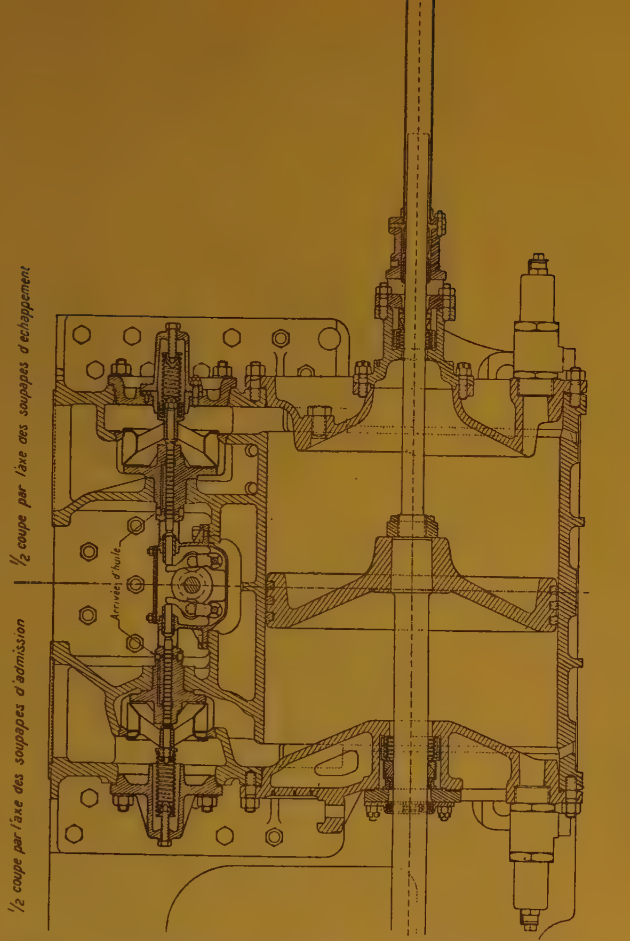
1/2 coupe par l'axe des soupapes d'échappement
1/2 coupe par l'axe des soupapes d'admission
Arrivée d'huile

Fig. 4. — Low pressure cylinders — longitudinal section.

Note: 1/2 coupe par l'axe des soupapes d'admission = Half section through steam valves. — 1/2 coupe par l'axe des soupapes d'échappement = Half section through exhaust valves.

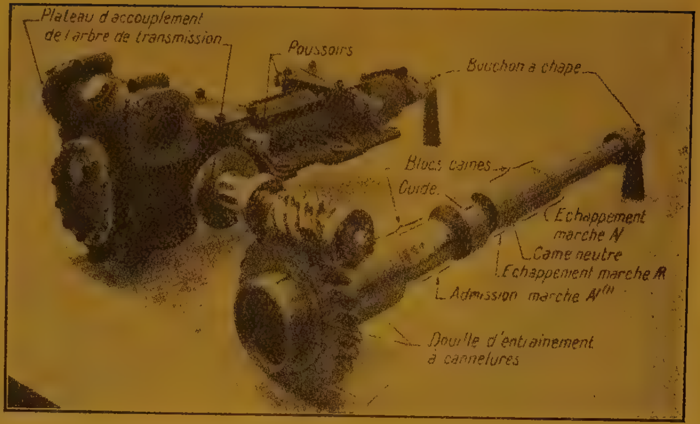

Fig. 5. — Low-pressure cam boxes.

Explanation of French terms:

Plateau... de transmission = Reversing shaft flexible coupling. — Poussoirs = Plungers. — Bouchon à chape = Cap plug. — Blocs cames = Cam sets. — Guide = Guide. — Echappement marche AV = Fore gear exhaust cam. — Came neutre = Neutral cam. — Echappement marche AR = Back gear exhaust cam. — Admission marche AV (1) = Fore gear steam cam (1). — Douille d'entraînement à cannelures = Splined driving bush.

(1) The neutral (by-pass) cam and the steam cams (back gear) are inside the driving splined bush and are not visible in the photograph.

The table below gives the valve events for the different notches :

Gear.	Corresponding cut-offs		VALVE LIFTS			
			h. p. cylinders		l. p. cylinders	
	h. p.	l. p.	Steam.	Exhaust.	Steam.	Exhaust.
			millimetres			
Fore	Full	Full	18	20	21	23
	65	75	18	20	21	23
	50	63	18	20	21	23
	45	56	18	20	21	23
	40	50	18	20	21	23
	35	44	16	20	16	23
	30	40	8	16	8	16
Mid gear	0	0	0	8	0	8
Back	40	50	8	16	8	16
	50	63	16	20	16	22
	Full	Full	18	20	21	23

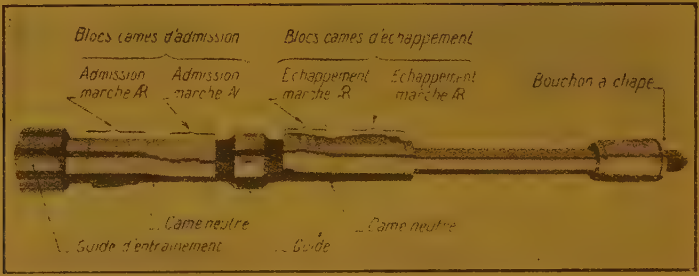

Fig. 6. — Low pressure cam shaft.

Explanation of French terms:

Blocs cames d'admission = Steam cam sets. — Admission marche AR = Steam, back gear. — Admission marche AV = Steam, fore gear. — Blocs cames d'échappement = Exhaust cam blocks. — Echappement marche AR = Exhaust, back gear. — Echappement marche AV = Exhaust, fore gear. — Bouchons à chape = Cap plugs. — Guide d'entraînement = Driving guide. — Came neutre = Mid gear (by-pass) cam.

6. *Metals used for the different parts of the motion.* — The valves are made of special steel not heat-treated. (Tensile = 40 kgr./mm² [25.4 Eng. tons per sq. inch] with not less than 30 % elongation).

The valve spindles, cams, intermediate levers, rollers, worms, and rack are case-hardened and tempered steel.

The pins of the rollers are made of nickel bronze and the wheels of bronze.

7. *Checking the valve setting.* — When checking the valve setting, three operations are required :

Setting the reversing gear. — Each cam box has a graduated scale which shows the cam on which the rollers are running and therefore shows the corresponding cut-off.

By means of these scales, the four cam shafts are set to the same cut-off; the

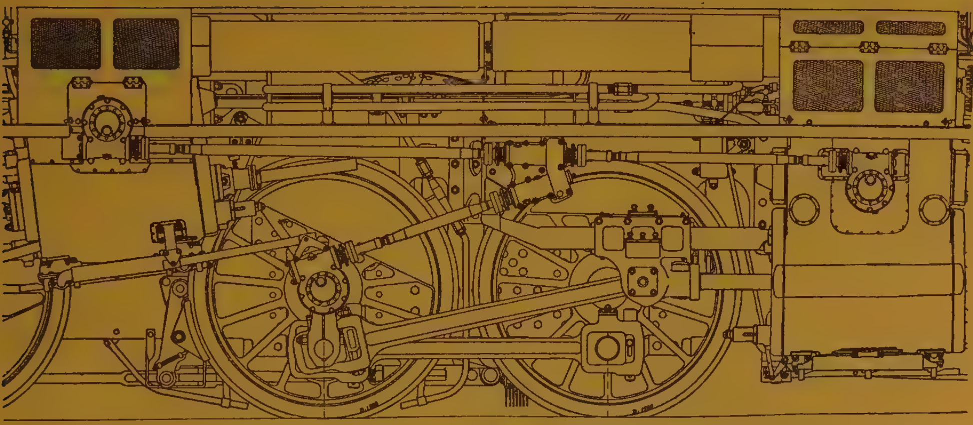

Fig. 7. — The drive from the wheels and axles to the cam shafts.

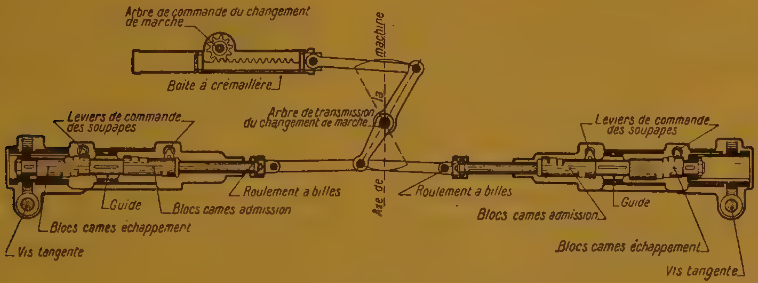

Fig. 8. — Reversing gear diagram.

Explanation of French terms:

Arbre de commande... = Reversing gear shaft. — Boîte à crémaillère = Rack and pinion box. — Leviers de... des soupapes = Levers operating the valves. — Vis tangente = Worm. — Blocs cames échappement = Exhaust cam sets. — Blocs cames admission = Steam cam sets. — Roulement à billes = Ball bearing. — Arbre de transmission... = Reversing gear bridle rod. — Axe de la machine = Engine centre line.

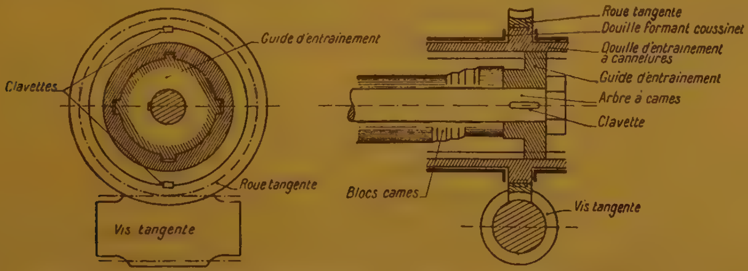

Fig. 9. — Diagram showing the transmission of the rotary motion and the cross movement.

Explanation of French terms:

Clavettes = Keys. — Guide d'entraînement = Driving bush. — Roue tangente = Worm wheel. — Vis tangente = Worm. — Blocs cames = Cam sets. — Douille formant coussinet = Bush which acts as a bearing. — Douille d'entraînement = Splined driving bush. — Arbre à cames = Cam shaft.

reversing gear is then put to the same notch and the length of the various connecting links adjusted to suit.

Adjusting the length of the valve spindles. — A number of location lines are scribed on the periphery of the driving splined bush in each gear box, and a location mark is scribed on the fixed liner. These guiding marks, which are visible on removing a cap, correspond to the opening and closing positions of the steam and exhaust valves for a given cut-off.

By rotating the worm, one of the lines scribed on the driving bush is brought into line with the mark on the fixed liner; the valve should now be just seated (easily felt by turning it). The length of the valve spindle is set to suit by inserting washers of the correct thickness, between the valve ad the spindle collar.

Adjusting the driving shafts. — In addition to the scribed lines mentioned above, the driving splined bush has two lines scribed on it corresponding to the front and back dead centres.

When erecting the driving shaft of a cam box, the driving wheel of the corresponding cylinder is set to a dead centre and the scribed line in the driving bush is brought in line with that in the fixed bush; the driving shaft can then be coupled to the cam box.

8. *Lubrication of the valve gear.* — The valve spindles are lubricated by a pump with anticarbonisers at the h.p. cylinders (¹).

The driving gear boxes, intermediate gear boxes and the cam boxes are oil tight and are filled with oil to a definite level; the different parts contained in these boxes are thus splash lubricated.

c) *Driving wheels and axles.*

The driving wheels are 1.500 m. (4 ft. 11 in.) in diameter on the tread. As mentioned earlier the third and fourth pairs of driving wheels are coupled by a pair of inside coupling rods; they have, of course, crank axles. The cranks are built up from five pieces and are balanced in themselves.

On one side of the engine :

— the h.p. crank pin leads the l.p. pin by 172° 52′ 30″.

— the inside coupling rod is at 180° with the forward outside coupling rod.

— the two h.p. and the two l.p. crank pins are set at 90° to one another.

d) *Side movement of the axles.*

The axle boxes of the second pair of coupled wheels have been given 25 mm. (1 inch) side movement each way relatively to the frame and are fitted with a centering device with conical coiled springs.

The fourth, fifth and sixth pairs of coupled wheels have thin flanges.

This 151.A locomotive can take curves of 140 m. (7 chains) radius on a gauge of 1.45 m. (4 ft. 9 in.).

e) *Spring gear.*

In the longitudinal plane the spring-supported weight is carried on three points :

— leading truck with coiled springs and the second pair of wheels with laminated springs connected by equalisers (one cross equaliser in front of the second pair of wheels and one longitudinal equaliser on the engine centre line);

— the third, fourth, fifth and sixth pairs of coupled wheels by laminated

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(¹) The mechanical lubricator used is a 12-feed Bourdon FSA with 3 feeds for each cylinder, as follows :

— one for the cylinder;

— one for the steam valve spindles (split feed);

— one for the exhaust valve spindles (split feed).

springs equalised on each side of the engine;

— the trailing truck.

5. Fittings.

a) *Safety valves.*

The two safety valves are of the Consolidated direct loaded type.

b) *Regulator.*

A double-seated regulator is fitted, with valve guided below the lower seat.

c) *Blast.*

The 151.A locomotives were originally fitted with the P.L.M. variable clover-leaf type blast pipe tops. As a result of the excellent results obtained on the 241.C-1 locomotive and on the *Pacific* engines with a double variable blast pipe with bridge pieces and petticoat pipe of the P.-L.M. type, the same design of blast was fitted at once to locomotive 151.A, which then underwent dynamometer car trials, and will be fitted later on to the 9 other engines of the class.

d) *Brake.*

The engine is fitted with the Westinghouse-Henry combination air brake.

A bi-compound air pump is fitted.

The brake acts on four pairs of coupled wheels only; 66 % of the weight, on the rails, of the five pairs of coupled wheels, is braked.

e) *Counter-pressure steam brake.*

By means of a water and steam injector cock, a mixture of water and steam can be discharged into the l.p. exhaust for counter-pressure working.

f) *Sanders.*

Two Gresham steam sanders are fitted, the steam being taken from the dome and the sand delivered in front of the third and sixth pairs of wheels or behind the third and fifth pairs.

g) *Steam heating.*

The locomotive is fitted with a pressure-reducing valve of the Mason type for supplying steam for heating the train.

h) *Indicating recorders for speed, steam heating pressure, and signals passed at danger.*

The engine is fitted with a Flaman indicating speed recorder, an instrument which records signals passed at danger, besides giving a warning signal, and an indicating recorder of the steam pressure in the steam heating pipe.

i) *Lighting.*

The engine is fitted with electric light, the current being generated by a Sunbeam 0.5-kw. turbo-generator carried at the leading end on the right hand side on the l.p. cylinder casing.

6. Leading dimensions of the locomotive.

The leading dimensions of locomotive 151.A are given in figure 10.

III. — Trials carried out with locomotive 151.A and results obtained.

A. — Trials with the original design of blast pipe (the P. L. M. clover-leaf type).

1. *Trials with trains in ordinary working.*

Dynamometer car trials with engine 151.A-10, fitted with its original blast pipe and working ordinary trains, were carried out, not only on the *Paris-Lyons-Mediterranean* System, but also on the French *Est* and *Nord* Railways.

We will mention only the more interesting result obtained.

On the 22nd May, 1933, locomotive 151.A-10 worked a train weighing 2 599 t. (2 558 Engl. tons) on the French *Nord*

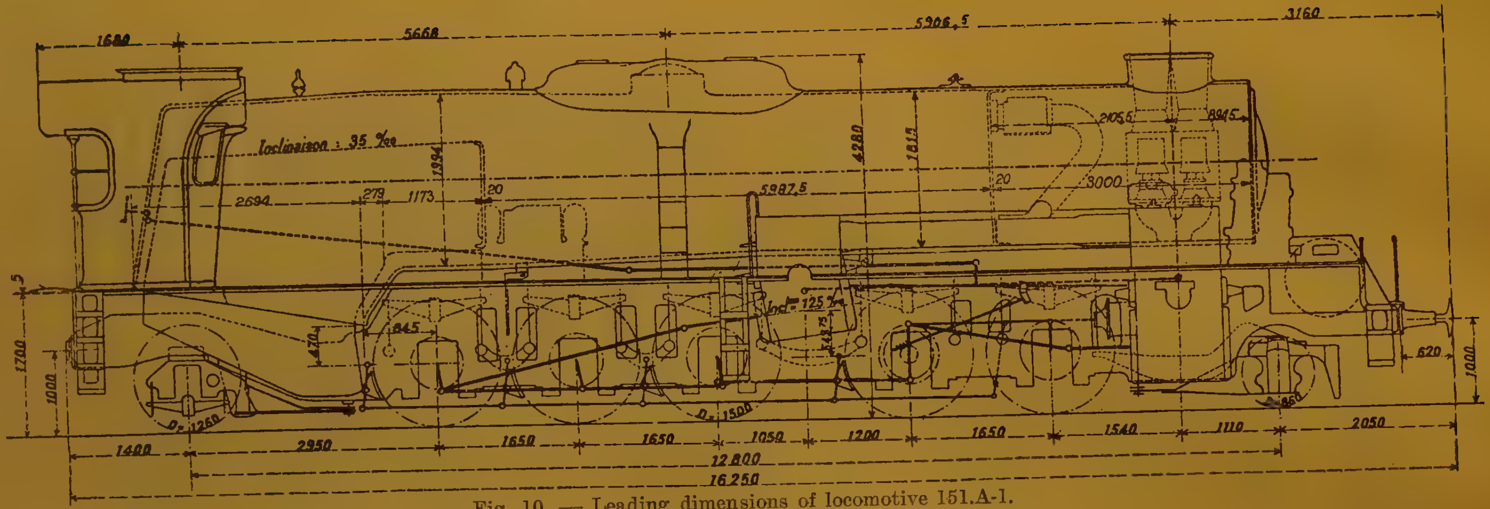

Fig. 10. — Leading dimensions of locomotive 151.A-1.

Boiler	Pressure	p = 20 kgr./cm² (*284 lb. per squ. inch*).
Grate	Length 2.503 m. (8 ft. 2 9/16 in.), width 2.000 m. (6 ft. 6 3/4 in.), area G	= 5 m² (*3.8 sq. feet*).
	Slope of grate	= 17.1 %.
Heating and superheating surfaces.	Firebox	23.24 m² (*250.1 sq. feet*).
	Tubes	220.53 m² (*2 373.8 sq. feet*).
	Total	243.77 m² (*2 623.9 sq. feet*).
	Superheater	91.64 m² (*986.4 sq. feet*).
Volumes (with water level 85 mm. (*3 3/8 in.*) above crown of box).	Water in the boiler	11 790 l. (*416 cu. feet*).
	Steam	3 800 l. (*134 cu. feet*).
	Total	15 590 l. (*550 cu. feet*).
Tubes	Length between tube plates	5.9875 m. (*19 ft. 7 11/16 in.*).
	Number of smooth tubes :	
	51 × 55-mm. (2 in. — 2 3/16 in.) tubes	141.
	135 × 143-mm. (5 5/16 in. — 5 5/8 in.) flues	33.
	28 × 35-mm. (1 1/8 in. — 1 3/8 in.) superheater elements	33.
Firebox	Copper, smoke box tube plate, steel.	
	Inside length :	
	at the top (with combustion chamber)	3.707 m. (*12 ft. 2 in.*).
	at the bottom	2.467 m. (*8 ft. 1 1/8 in.*).
	Inside width :	
	front (on the boiler centre line)	1.671 m. (*5 ft. 5 13/16 in.*).
	at the bottom	2.000 m. (*6 ft. 6 3/4 in.*).
	Inside height :	
	below the foundation ring — front	2.129 m. (*6 ft. 11 53/64 in.*).
	below the foundation ring — back	1.554 m. (*5 ft. 1 3/16 in.*).
	above the boiler centre line — back	0.449 m. (*1 ft. 5 43/64 in.*).
		0.318 m. (*1 ft. 33/64 in.*).

Plate thicknesses.

Firebox top	0.015 m. (*19/32 in.*).
Firebox back plate	0.015 m. (*19/32 in.*).
Firebox tube plate	0.020 m. (*25/32 in.*).
Firebox side casing	0.014 m. (*9/16 in.*).
Firebox top casing	0.022 m. (*7/8 in.*).
Firebox throat sheet	0.022 m. (*7/8 in.*).
Firebox back plate	0.015 m. (*19/32 in.*).
Smoke box tube plate	0.020 m. (*25/32 in.*).
Barrel { Back and middle rings	0.022 m. (*7/8 in.*).
Barrel { Front ring	0.020 m. (*25/32 in.*).

Chimney — Minimum diameter of each of the two chimneys . . . 0.394 m. (*15 33/64 in.*).

Brick arch — Length . . . 1.200 m. (*3 ft. 11 15/64 in.*).

Air passage areas

Ashpan	l_1 = 1.040 m² (*11.19 sq. feet*).
Middle of tubes	l_2 = 0.633 m² (*6.81 sq. feet*).

Ratios — $\frac{l_1}{G} = 0.208.$ $\frac{l_2}{G} = 0.127.$

Safety valves

Number	2.
Diameter	0.1016 m. (*3 15/16 in.*)

Feed water equipment

1 type U-1 injector on the right hand side.
1 type 120-B Dabeg pump on the left hand side.

Wheel and axles

Diameter of wheels on the tread with 70-mm. (2 3/4 in.) tyres:

1st pair of wheels	0.860 m. (*2 ft. 9 7/8 in.*).
2, 3, 4, 5 and 6th pairs of wheels	1.500 m. (*4 ft. 11 in.*).
7th pair of wheels	1.260 m. (*4 ft. 1 19/32 in.*)
Distance between tyres, inside	1.360 m. (*4 ft. 5 35/64 in.*).

Journals:

	Diameter.	Length.	Centres.
1st pair of wheels	170 mm. (*6 11/16 in.*)	270 mm. (*10 5/8 in.*)	1.090 m. (*3 ft. 7 in.*)
2, 3, 4 and 5th pairs of wheels	220 mm. (*8 11/16 in.*)	280 mm. (*11 1/32 in.*)	1.028 m. (*3 ft. 4 15/32 in.*)
6th pair of wheels	240 mm. (*9 7/16 in.*)	280 mm. (*11 1/32 in.*)	1.028 m. (*3 ft. 4 15/32 in.*)
7th pair of wheels	200 mm. (*7 7/8 in.*)	280 mm. (*11 1/32 in.*)	1.120 m. (*3 ft. 8 in.*)

Crank pins

Description.	Diameter.	Length.	Centres.
Connecting rods, big ends:			
h. p.	160 mm. (*6 5/16 in.*)	180 mm. (*7 3/32 in.*)	2.200 m. (*7 ft. 2 5/8 in.*)
l. p.	130 mm. (*5 1/8 in.*)	150 mm. (*5 29/32 in.*)	2.100 m. (*6 ft. 10 43/64 in.*)
Outside coupling rods:			
2nd pair of wheels	135 mm. (*5 3/8 in.*)	85 mm. (*3 11/32 in.*)	1.735 m. (*5 ft. 8 5/16 in.*)
3rd pair of wheels	210 mm. (*8 1/4 in.*)	120 mm. (*4 23/32 in.*)	1.780 m. (*5 ft. 10 in.*)
4th pair of wheels	135 mm. (*5 3/8 in.*)	120 mm. (*4 23/32 in.*)	1.818 m. (*5 ft. 11 19/32 in.*)
5th pair of wheels	135 mm. (*5 3/8 in.*)	120 mm. (*4 23/32 in.*)	1.818 m. (*5 ft. 11 19/32 in.*)
6th pair of wheels	210 mm. (*8 1/4 in.*)	120 mm. (*4 23/32 in.*)	1.818 m. (*5 ft. 11 19/32 in.*)
Inside coupling rods:			
3rd pair of wheels	230 mm. (*9 1/16 in.*)	130 mm. (*5 1/8 in.*)	0.358 m. (*1 ft. 2 in.*)
4th pair of wheels	230 mm. (*9 1/16 in.*)	130 mm. (*5 1/8 in.*)	0.358 m. (*1 ft. 2 in.*)

Side play and side movement of wheels on each side

Leading truck	Side play	116 mm. (*4 35/64 in.*).
2nd pair of wheels	Do.	26 mm. (*1 in.*).
3rd pair of wheels	Do.	1 mm. (*3/64 in.*).
4th and 5th pair of wheels	Thinned down flanges	11 mm. (*7/16 in.*).
6th pair of wheels	Do.	6 mm. (*1/4 in.*).
Trailing truck	Side play	111 mm. (*4 23/64 in.*)
Minimum radius of curve engine can run round on 1.45-m. (4 ft. 9 in.) gauge track		140 m. (*7 chains*).

	Description.	Helical, laminated.			Flexibility.
		No. of leaves.	Width.	Thickness.	
Springs	1st pair				4.43 mm. per t. (*0.177 inch per Engl. ton*).
	2nd, 3rd, 4th, 5th and 6th pairs	17	110 mm. (*4 11/32 in*).	12 mm. (*15/32 in.*)	6.31 (*0.255 inch per Engl. ton*).
	7th pair	12	140 mm. (*5 1/2 in.*)	11 mm. (*7/16 in.*)	4.31 (*0.175 inch per Engl. ton*)

		h. p.	l. p.
Motion	Cylinder diameter	480 mm. (*18 7/8 in.*)	745 mm. (*29 5/16 in.*)
	Piston stroke	650 mm. (*25 5/8 in.*)	700 mm. (*27 1/2 in.*)
	Swept volume, 1 cylinder	118 l. (*4.16 cu. ft.*)	305 l. (*10.76 cu. ft.*)
	Volume of receiver	685 l. (*24.2 cu. ft.*)	
	Main steam pipe area	0.0201 m² (*31 sq. in.*)	0.452 m² (*70 sq. in.*)
	Blast pipe area	0.0452 m² (*70 sq. in.*)	0.0572 (*88.7 sq. in.*)
	Diameter of steam valves	180 mm. (*7 3/32 in.*)	195 mm. (*7 43/64 in.*)
	Diameter of exhaust valves	180 mm. (*7 3/32 in.*)	240 mm. (*9 7/16 in.*)
	Maximum lift of steam valves	18 mm. (*45/64 in.*)	21 mm. (*53/64 in.*)
	Maximum lift of exhaust valves	20 mm. (*25/32 in.*)	23 mm. (*29/32 in.*)
	Maximum sectional area through steam valves	204 cm² (*12.44 cu. in.*)	257 cm² (*15/68 cu. in.*)
	Maximum sectional area through exhaust valves	226 cm² (*13.78 cu. in.*)	347 cm² (*21.17 cu. in.*)
	Length of connecting rods between centres	3.000 m. (*9 ft. 10 1/8 in.*)	1.900 cm. (*6 ft. 2 25/32 in.*)
	Gudjeon pins: Diameter	105 mm. (*4 1/8 in.*)	105 mm. (*4 1/8 in.*)
	Gudjeon pins: Length	100 mm. (*3 5/16 in.*)	100 mm. (*3 5/16 in.*)

Power	Average theoretical tractive power $F = \frac{pd^2l}{D} + \frac{p'd'^2l'}{D} = =$	29 920 kgr. (65 960 lb.)
	Ratio of adhesive weight P to theoretical weight $\frac{P}{F} =$	3.09.
	Horse power $= K\sqrt{G\,Cr\,p}$	2 820.
Centre of gravity	Engine in working order. Distance from face of front buffers	8.730 m. (*28 ft. 7 45/64 in.*).
Weights	Locomotive empty, tyres half worn	110 030 kgr. (*242 570 lb.*).
	Hot water, at normal water level	10 630 kgr. (*23 435 lb.*).
	Fuel on the grate	1 500 kgr. (*3 305 lb.*).
	Sand (sand box half full)	250 kgr. (*550 lb.*).
	Engine in ordinary running order:	
	1st pair of wheels	11 840 kgr. (*26 100 lb.*).
	2nd pair of wheels	18 710 kgr. (*41 250 lb.*).
	3rd pair of wheels	18 500 kgr. (*40 785 lb.*).
	4th pair of wheels	18 500 kgr. (*40 785 lb.*).
	5th pair of wheels	18 500 kgr. (*40 785 lb.*).
	6th pair of wheels	18 500 kgr. (*40 785 lb.*).
	7th pair of wheels	17 860 kgr. (*39 375 lb.*).
	Total	122 410 kgr. (*269 865 lb.*).

Railway, from Lens to Le Bourget, a distance of 223 km. (138.6 miles) with maximum gradients of 1 in 200, the train consisting of 51 vehicles, 49 of which were with bogies.

The timings were as follows :

Stations.	Distances. Km, (*miles*).	Running time.	Average speed. Km/h. (*miles/h.*)
Lens.			
Longueau.	83.6 *(51.9)*	1 hour 32 1/2 m. .	54.2 *(33.7)*
Le Bourget	139.4 *(86.7)*	2 hours 47 m. . .	50.0 *(31.0)*

During this run, the maximum drawbar horse power recorded exceeded 2 700, the sustained horse power being about 2 300.

2. *Special constant-speed trials.*

Special constant-speed trials have been made to get comparative data on the relative merits of the original P.L.M. clover-leaf blast pipe and the double P.L.M. type blast pipe (with bridge pieces).

These trials showed that at the speed of 75 km. (46.6 miles) an hour :

— with 45 % cut off the pressure in the boiler and the water level could not be kept up for a distance exceeding 30 km. (18.6 miles);

— with 50 % cut off the pressure and water level could not be kept up for more than 15 km. (9.3 miles).

The horse power recorded at the tender drawbar [30 m³ (6 600 Br. gallons capacity tender)] were :

H.P.	(6 600 Br. gallons capacity.)
2 450	(45 % — 75 km./h.)
2 480	(50 % — 75 km./h.)

B. — Trials with engine 151.A-1 with P.L.M. type double blast pipe (with bridge pieces).

Following the recent practice of the Paris-Lyons-Mediterranean Railway to carry out a series of tests on the « constant-speed method » with all new types of locomotives this engine after being got into good working order underwent a series of trials. (See our article in the *Revue Générale des chemins de fer* of January 1932, on the 241.B-1 high-pressure locomotive.)

Only the more interesting results obtained are given below :

1. *Tender drawbar pull and horse power.*

The drawbar pull (with 6 600-gallon tender) and horse-power are shown in figures 11 and 12 at speeds V = 45, 60, 75, and 85 km. (28.0, 37.3, 46.6 and 52.8 miles) an hour, and at cut-offs *i* = 35, 40, 45, 50 and 65 %.

The full-line curves obtained at constant output over a distance of 92 km. (57.2 miles) have been extended by dotted lines to include short-distance tests at 45 %, 85 km. (52.8 miles) per hour — 50 %, 75 km. (46.6 miles) per hour — 65 %, 60 km. (37.3 miles) per hour.

— The maximum *sustained horse power* over the distance of 92 km. (57.2 miles) was 2 892 at 75 km. (46.6 miles) an hour.

— Over a short run of 5 km. (3.1 miles) at 60 km. (37.3 miles) per hour, it was 3 248.

The power is much greater than that obtained with the old P.L.M. clover-leaf type blast pipe, and shows quite clearly that the new P.L.M. type double blast pipe (with bridge pieces) is much better.

We think it desirable to give details as to how these results were obtained. When speaking of the maximum power obtained during a trial, the term should be clearly defined. Is it the maximum power than can be maintained indefinitely, or is it the maximum power that can be maintained during a period of time *t*?

The continuous power output of a locomotive can be defined as the power the engine can maintain indefinitely (at least theoretically) during a trial at constant speed (in other words at constant output).

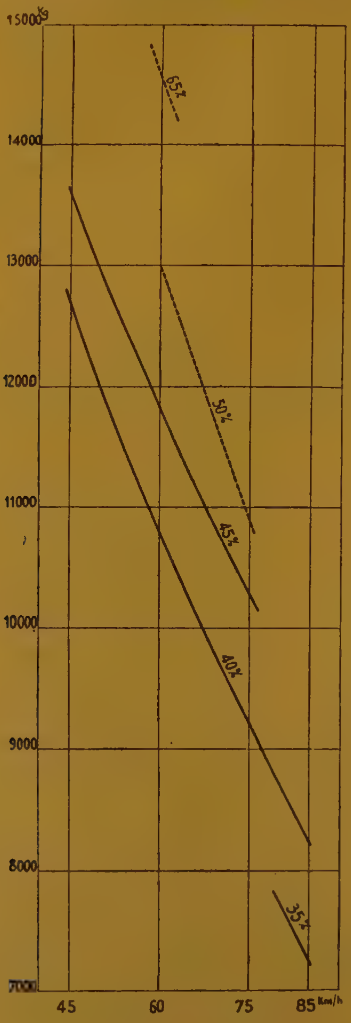

Fig. 11. — Tender drawbar pull.

The « momentary » power that can be maintained for a period *t* (1 hour, or 5 minutes, for example) is the power obtainable at constant speed with some drop in water level in the boiler (in other words, the output is no longer constant but use is made of the reserve heat units in the boiler).

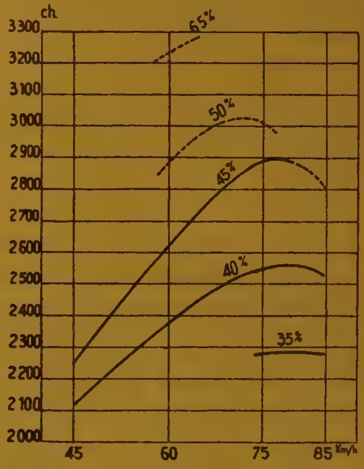

Fig. 12. — Tender drawbar horse power.

The cut-off in the cylinders and consequently the power developed falls off as the period of constant output is lengthened.

Another cause of the falling-off of power on long runs is the clinkering up of the grate and this depends on the rate of firing and the time the fuel takes to burn. The blast has to be heavier and heavier still, the longer a constant output is maintained. Now, any tightening up of the blast pipe involves increased back pressure in the cylinders and consequently a reduction in power (¹).

In connection with these remarks, all our tests at constant speed are made between Laroche and Les Laumes (102 km.

(¹) With fixed blast pipes, when a high rate of combustion is particularly needed for long runs, the blast pipe must be designed to suit, and consequently, when the engine is not being pressed, power is lost, or what comes to the same thing, the specific consumption of the engine is increased.

= 63.4 miles), and unless specially noted otherwise, the maximum powers mentioned are momentary powers recorded over this run (in the particular case of the trials of locomotive 151.A-1, a permanent way speed restriction made it necessary to shorten the trial run to 92 km. = 57.2 miles).

2. *Water and coal consumption.*

As we could not make the final adjustments to the double blast pipe when working ordinary trains, these trains being too light for so powerful a locomotive, we had to make some further adjustments in the diameter of the bridge pieces during the constant-speed trials.

The results obtained before and after this alteration are shown in figures 13 to 16, marked O and + respectively.

It will be seen that the results marked O show a higher superheat and consequently a higher temperature in the l.p. exhaust. The result was an improvement of the consumption (¹), as figures 13 and 14 clearly show.

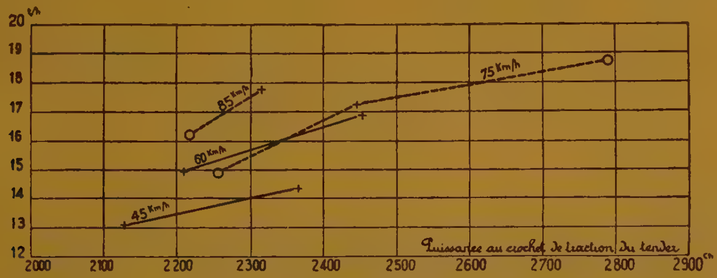

Fig. 13. — Water used per hour.

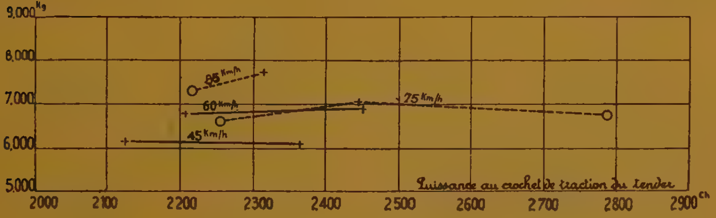

Fig. 14. — Water used per tender drawbar horse power-hour.

Note: Puissance au crochet de traction du tender = Tender drawbar horse power.

a) *Water consumption.* — The total water consumption per hour and per tender drawbar horse power is shown in figures 13 and 14 against the tender drawbar horse power.

The consumption per tender drawbar horse-power-hour increases by 6 to 8 kgr. (13.2 to 17.6 lb.) when the speed is increased from 45 to 85 km. (28 to 52.8 miles) an hour.

b) *Coal consumption.* — Figures 15 to 16 give in terms of the tender drawbar horse power :

— the total consumption per hour and the hourly rate of firing;

(¹) The improvement is due to the temperature of the steam admitted to the H.P. cylinders being higher and the exhaust steam temperature on leaving the l.p. cylinders is farther from the saturated point (in the tests marked +, the l.p. exhaust steam showed only a few degrees superheat while in those marked O it exceeded 20° C. [68° F.]).

— the consumption per drawbar horse-power-hour.

During the trials :

— the rate of fuel consumption varied from 368 to 584 kgr./m^2 (75.3 to 127 lb. per sq. foot) per hour;

— the coal consumption per tender drawbar horse-power-hour varied from 0.85 to 1.2 kgr. (0.18 to 0.24 lb.) (2).

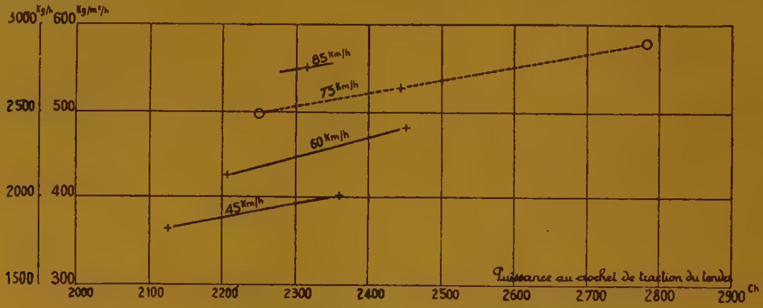

Fig. 15. — Coal used, total and per hour. Rate of firing (per sq. meter of grate per hour).

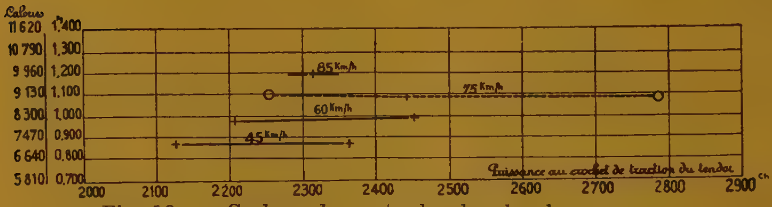

Fig. 16. — Coal used per tender drawbar horse power.

To conclude, we give hereafter the most characteristic figures obtained on the trial during which a drawbar horse power of 2 892 was maintained over a run of 92 km. (57.2 miles) at absolutely constant speed (without any stop or speed reduction):

Cut-off	h.p. cylinders	45 %
	l.p. cylinders	56 %
Blast pipe setting		4.5/10
Speed :		74.8 km./h. *(46.5 miles per hour).*
Pressure	Boiler (1)	20.8 kgr./cm^2 *(295.4 lb. per sq. inch).*
	h.p. steam chests . .	19.5 kgr./cm^2 *(277.2 lb. per sq. inch).*
	receiver	4.85 kgr./cm^2 *(69.0 lb. per sq. inch).*
	exhaust.	0.210 kgr./cm^2 *(3 lb. per sq. inch).*
Steam temperature in	header	403° C. *(757° F.)*
	h.p. steam chests	397° C. *(714.6° F.)*
	receiver	245° C. *(473° F.)*
	exhaust	126° C. *(258.8° F.)*

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(2) The calorific value of the coal used is or exceeds 8 300 calories (14 940 B.T.U./lb.).

(1) The safety valves of engine No. 151.A-1 were set at 21 kgr./cm^2 (298.7 lb. per sq. inch) during the trials in order to prevent any loss of steam through the safety valves blowing off.

Smokebox	Vacuum	195 mm. *(7.67 in.)* water.
	Combustion gas temperature	376° C. *(709° F.)*
Tender drawbar pull (on the level)		10 442 kgr. *(23 020 lb.)*
Tender drawbar horse power (on the level		2 892 H.P.
Rate of firing		584 kgr./m²/h. *(127 lb./sq. ft./hour).*
Coal consumption, total and per hour		2 920 kgr. *(6 437 lb.)*
Water used, per hour		18 500 kgr. *(4 068 Br. gallons).*

Mechanical efficiency of the engine $\left(\alpha = \frac{\Delta\lambda_R}{\Delta\lambda_T}\right)$	0.829
Theoretical thermal efficiency of the engine $\left(\rho_T = \frac{\Delta\lambda_T}{\lambda}\right)$	0.193
Actual thermal efficiency of the engine $\left(\rho_M = \frac{\Delta\lambda_R}{\lambda} = \rho_T\,\alpha\right)$	0.160
Mechanical efficiency of the h.p. cylinders	0.935
Mechanical efficiency of the l.p. cylinders	0.709

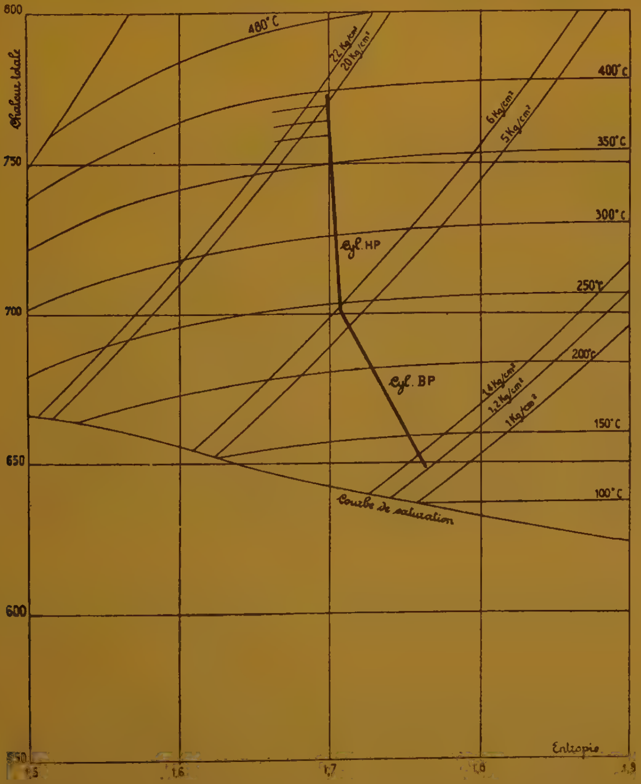

Fig. 17. — Mollier diagram.

Test conditions : $i_{\text{H.P.}} = 45$ %, $i_{\text{B.P.}} = 56$ %, V = 75 km (*46.6 miles*) per hour.

Note: Entropie = Entropy. — Chaleur totale = Total heat. — Courbe de saturation = Saturation curve.

Figure 17 reproduces a Mollier diagram showing the way the steam is used in the cylinder.

It should be noted that we were able to develop 2 892 horse power for 1 1/4 hours because the new blast pipe arrangement enabled us to burn nearly *three tons of coal per hour.*

P. S. — Since the above lines were written, further trials have been made with engine 151.A-1, after the double blast pipe had been slightly modified. During a constant-speed test carried out on the 19th December, 1933, with an atmospheric temperature of — 3° C. (26.6° F.), *over 3 000 drawbar horse power* (3 002 to be exact) was developed with 50 % cut-off in the h.p. cylinders at 75 km. (46.6 miles) an hour, without the slightest check or slowing down, *over a run exceeding 60 km.* (37.3 miles). Permanent way restrictions prevented us continuing the trials over a longer distance.

[**62**. (01 & 669]

X-ray determination of depth of cold working by machining,

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(Mechanical Engineering.)

Considerable interest has been shown by mechanical engineers in the depth of cold working produced by machining metals and alloys (1). Hardness determinations are generally used for measuring this quantity; but it should be kept in mind that this method measures only one of the effects of cold work, namely, work hardening, which will vary in magnitude for the same amount of work from one material to another. A determination of depth of cold working by hardness measurements on a material which work hardens very little must obviously be inaccurate.

When annealed metals and alloys are severely cold worked the original grains will be deformed under formation of slip planes and changes in crystal orientation, thus obliterating the original grain structure. This effect is observed in X-ray-diffraction photographs by the appearance of continuous rings forming a true Hull-Debye-Scherrer picture (fig. 1), instead of the separate double lines or spots which are reflected from the individual grains and are characteristic of the annealed material (fig. 4). Less severe working will destroy the regularity of the space lattice by removing a cer-

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(1) « Effect of Lathe Cutting Conditions on the Hardness of Carbon and Alloy Steels », by T. G. Digges. Paper presented at the Annual Meeting, New York, P. Y., December, 1933, of *The American Society of Mechanical Engineers.*

Contributed by the Special Research Committee on Cutting of Metals and presented at the Session on Metal Cutting, Stevens Institute of Technology, Hoboken, N. J., December 6, 1933, of the Annual Meeting, New York, N. Y., December 4 to 8, 1933, of *The American Society of Mechanical Engineers.*

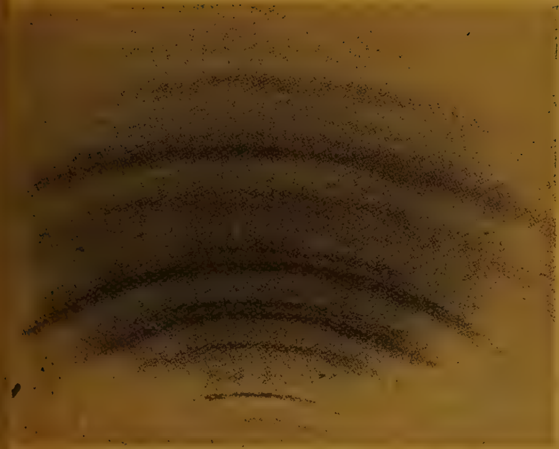
Fig. 1. — Sample No. 3 etched to 0.0033 inch below surface.

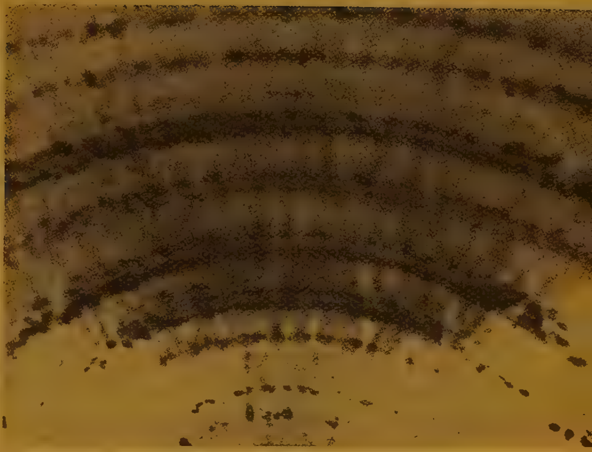
Fig. 2. — Sample No. 8 etched to 0.0050 inch below surface.

Fig 3. — Sample No. 8 etched to 0.0095 inch below surface. (Original enlarged twice.)

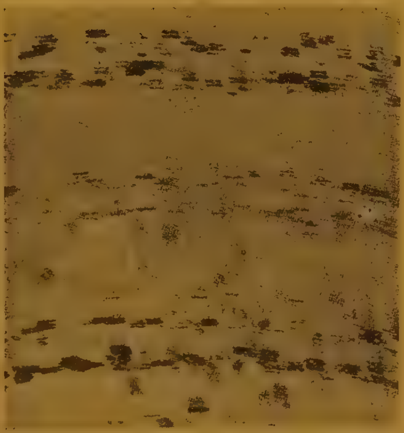
Fig. 4. — Sample No. 8 etched to 0.0112 inch below surface. (Original enlarged twice.)

tain number of atoms from their equilibrium positions and is particularly noticeable by a broadened and washed-out appearance of the spots (fig. 2). The pictures shown are all photographed by the molybdenum characteristic radiation.

We may define « depth of cold working » as the distance below the surface at which the effect of lattice deformation is no longer noticeable in the X-ray-diffraction picture. This quantity can be determined as follows : After annealing, an X-ray picture is taken of the sample as a record of the structure. The machining operation is then carried out under conditions as carefully controlled as possible, the machined surface is etched to remove a definite thickness of material, and a new X-ray picture is taken and is compared with the first picture. If the two pictures are identical, the new surface produced by etching is below the depth of the cold working. If the effect of work is still evident, the procedure is repeated in small steps until a picture is obtained which shows the same structure as was shown in the first picture. The total thickness of material removed by etching is then the depth of cold working.

Grinding off the surface for photographing instead of etching is out of the question, since grinding produces complete fragmentation of the surface grains and also comparatively deep cold working.

The success of the above method is due to the fact that surface layers of less than 0.001 inch will produce practically all the diffracted rays, when the beam of X-rays is directed against the flat sample of metal, for instance, brass, under an angle of 10°. This gives a powerful method for investigating the structure of thin layers even when they change quite rapidly in character from the surface inward, as is the case here.

Experimental program.

Milling operations. — Samples of cold-rolled 70-30 brass were annealed to produce a grain size of approximately 0.08 mm. For the milling operations, Brown and Sharpe end-mill cutters 1 inch in diameter with six teeth were used. The cutter in table 1 was new as purchased, while the one called « dull » was similar but worn.

The result of this work is shown in table 1 and graphically in figure 5. In the diagram the difference in thickness between the point where the annealed structure is obtained and the preceding one is indicated by a vertical line.

TABLE 1. — *Results of milling tests.*

Sample No.	Depth of cut, in.	Next-to-last etch		Last etch	
		Depth, in.	Picture.	Depth, in.	Picture.
1	0.004	0.0021	Mainly spots	0.0034	Spots sharp
2	0.016	...	...	0.0047	Spots sharp
3	0.032	0.0041	Almost sharp	0.0046	Spots sharp
4	0.064	0.0053	Almost sharp	0.0069	Spots sharp
5[a]	0.0166	0.0166	Rings and spots	0.0220	Spots sharp
6[b]	0.064	...	...	0.0078	Almost sharp
7[c]	0.064	...	...	0.0068	Almost sharp

[a] Dull cutter. — [b] Feed, 0.014 inch per revolution. — [c] 342 r.p.m.

Turning operations. — The material used was a leaded brass analyzing 61.7 % Cu, 35.0 % Zn, and 3.2 % Pb. After annealing the samples were turned under the following conditions : Cuts were taken on a Springfield tool-room lathe equipped with a dynamometer (2) to measure the force on turning. With a set-up of 94 r.p.m., the cutting speed was approximately 40 f.p.m. The tool was of a shape almost universally used for brass cutting and had the following angles : 0-deg. back and side rake, 6-deg. front and side clearance, 10-deg. end cutting angle, and a 0.010-inch nose radius. Cutting was done dry. The results are shown in table 2 and in figs. 6 and 7.

To illustrate the method, figure 1 shows a reproduction of the X-ray picture obtained from sample No. 3 etched to 0.0033 inch below the machined surface. The broad continuous lines are characteristic of the obliterated grain structure. Figure 2 shows a picture of sample No. 8 etched 0.0050 inch. Blurred crystal diffraction spots begin to appear superimposed on the continuous rings. Figure 3 is a picture of the same sample etched to 0.0095 inch showing almost sharp double lines. This may be compared with figure 4 of the same sample but 0.0112 inch below the surface. As will be seen, the double lines are on the whole more clear cut than in figure 3. Figure 4 is characteristic of the annealed structure and will not change on further etching. The two last pictures have been enlarged twice from the original negative to bring out the double lines

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(2) Described by O. W. BOSTON and C. E. KRAUS, *Trans. Am. Soc. Steel Treating*, vol. 21 (1933), p. 623.

TABLE 2. — *Results of turning tests.*

Sample No.	Depth of cut, in.	Feed, in. per rev.	Cutting force, lb.	Next-to-last etch Depth, in.	Next-to-last etch Picture.	Last etch Depth, in.	Last etch Picture.
1	0	0	0	0.0055	Sharp	0.0080	Sharp
2	0.0495	0.0052	44	0.0064	Almost sharp	0.0086	Sharp
3	0.051	0.0166	121	0.0137	Almost sharp	0.0165	Sharp
4	0.0495	0.0256	165	0.0180	Almost sharp	0.0197	Sharp
5*a*	0.015	0.0166	44	0.0034	Rings and spots	0.0095	Sharp
6*b*	0.030	0.0166	77	0.0095	Almost sharp	0.0150	Sharp
7	0.015	0.0166	44	0.0075	Almost sharp	0.0082	Sharp
8	0.030	0.0166	77	0.0095	Almost sharp	0.0112	Sharp

(*a*) Left out of graph since repeated experiment with sample No. 7 gives a closer value.
(*b*) Left out of graph since repeated experiment with sample No. 8 gives a closer value.

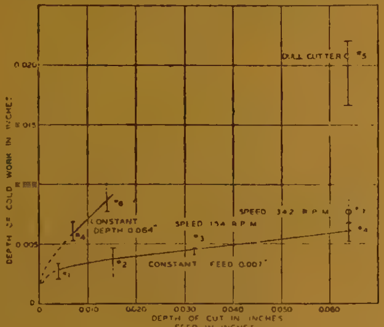

Fig. 5. — Results of milling tests.

Discussion of results.

1. The depth of cold working increases more rapidly with increase in feed than with increase in the depth of cut for the tools and materials used. In milling (see fig. 5), a doubling of the feed from 0.007 to 0.014 inch increases the depth of working from about 0.006 to 0.0085 inch, or about 40 %, while a doubling in the depth of cut from 0.016 to 0.032 inch increases the depth of cold work from 0.0039 to 0.0046 inch, or about 20 %. For the turning operations (fig. 6), a doub-

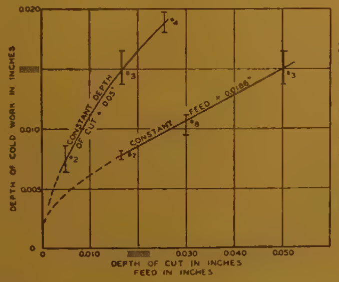

Fig. 6. — Results of turning tests.

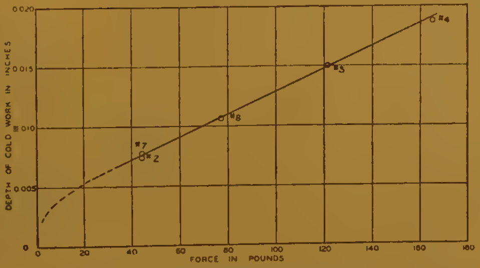

Fig. 7. — Depth of cold work as a function of cutting forces.

ling of the feed from 0.010 to 0.020 inch increases depth of cold working from 0.011 to 0.0165 inch, or 50 %, while the corresponding increase in feed only brings about an increase in depth of cold work from 0.006 to 0.0085 inch, or 25 %.

Comparing these results with those of Digges for steels and assuming that work hardening as determined by him is proportional to depth of cold work as demined here, a discrepancy will be noted, since Digges states that work hardening is increased equally by changes either in feed or in depth of cut.

2. Figure 7 shows the depth of cold working in turning plotted as a function of the cutting force. The connection is a strictly linear one.

3. An increase in depth of cold work of over 300 % is found on using a dull cutter instead of a sharp one in the milling experiments. According to the results obtained above, this depth of cold work would indicate a great force expended on cutting. A pronounced orientation of the crystalline structure was found in this sample, similar to that observed on cold rolling. This effect was noticed even at a depth of 0.0115 inch below the machined surface.

4. Increase in speed of milling from 154 to 342 r.p.m. does not increase the depth of work appreciably.

Acknowledgments.

The authors are indebted to W. A. Pearl who carried out the milling experiments. They are very grateful to Prof. O. W. Boston, Director of the Department of Engineering Shops, for the loan of milling cutters, and for illuminating discussions on the art of metal cutting. C. E. Kraus, of the same department, kindly prepared the latter samples and also took readings of the turning forces.

[625. 23 & 656. 221]

Wind flume experiments on the atmospheric resistance of railway vehicles,

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Communication from the Technical Institute on Aerodynamical Research
at the Higher Technical School, Berlin.

(Zeitschrift der Vereines Deutscher Ingenieure-VDI.)

The trials so far carried out in wind flumes, on railway vehicles, have nearly always been made to ascertain the atmospheric resistance of isolated vehicles, such as fast rail motor coaches and locomotives. The following note is intended as a contribution to the question if the wind flume lends itself to the determination of the atmospheric resistance of trains. By means of data taken from recently published articles, the author begins by a brief description of the aerodynamic principles of tests with models, the practical usefulness of which has been shown in the case in question by the measurements obtained in the wind flume of the « Berliner Institut für Technische Strömungsforschung ». In addition to the values of the atmospheric resistances, which vary with the design of the vehicles, this note describes a means whereby the atmospheric resistance of an intermediate vehicle in a train and the end vehicle can be determined.

* * *

The efforts now being made to raise the commercial speed of trains (1) make it necessary to know the resistances opposing the forward motion of the train with much greater accuracy than when the speed did not exceed some 110 km. (68 miles) an hour. Formerly, except for a few theorists, the railway engineers, in fact, only considered the *total resistance* and endeavoured to express it by the simplest possible mathematical formula. They preferred to use such expressions as $W = a + b\ v^2$, or $W = a + bv + c\ v^2$, in which a, b and c, are constants or at least values independent of the speed v.

These formulae were obtained by interpolation of the results of trial runs. They are not merely useful, they are essential so long as it is a question of getting out timings or calculating the dimensions of locomotives for a definite service within the range of speeds selected. It is, however, an absolute error to consider such simple formulæ, obtained by interpolation, as natural laws because, on the contrary, the results of trials lose their physical meaning when expressed in this form. FRANK (2) already raised this objection. When we reflect that, in the resistance to forward motion on straight level track, the losses through friction and shocks are affected by the weight and speed in a way still not fully known, that the air resistance is a function of the form of the body and the nature of its surface and varies approximately — but not exactly — with the square of the relative speed between the vehicle and the wind, and with the specific weight of the surrounding atmosphere, whilst it is wholly independent of the weight, we must admit that the total resistance, composed of such different elements, cannot be expressed accurately by any such simple equation.

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(1) See H. NORDMANN, Z.V.D.I. *(Zeitschrift des Vereines Deutscher Ingenieure)*, vol. 75 (1931), page 1237.

(2) A. FRANK, *Z.V.D.I.*, vol. 51 (1907), p. 95. See for fuller details on resistance formulæ, H. NORDMANN, *Glasers Annalen*, vol. 78 (1916), page 135.

The main factors, frictional resistance and air resistance, cannot be represented for all speeds by terms the index of which is a whole number. This is very clearly shown, as regards air resistance, by the example of a sphere dealt with later on. Now, a potential function the index of which is a whole number can only represent a natural law when it includes all phenomena coming under this law (3). The experiments with the pendulum by means of which A. Frank (4) thought he had definitely proved that, even at the lowest speeds, the air resistance varies as the square of the speed, should be accepted with caution as in the case of many other experiments of the period (5).

As the individual resistances are lost in the formula for the total resistance, the engineer designing a new locomotive or carriage for high speeds is quite unable systematically to reduce the individual resistances by properly arranging the constructional parts. This applies in particular to the atmospheric resistance which, as is known, forms the major part of the resistance to forward motion at high speeds.

Under the impulse of naval and aeronautical design the knowledge of the nature of the resistance of currents and in particular of air currents, and of the best methods of reducing such resistance, has grown considerably during the last three decades, although only a relatively small part of such knowledge has been used in connection with railways. The great success of aviation technique is due in many points to the methodical study of the aerodynamical conditions by means of tests based on the mechanics of similarity.

Air resistance and tests with models.

In dealing below with air resistance, we will limit ourselves to the case in which there is no side wind. It is true that in railway work this condition must, of necessity, be taken into consideration, but this difficult question cannot be dealt with until the simpler case of the resistance without side wind has been elucidated. Besides, at high speeds, the component of the side wind is small, but on the other hand it is very important in shunting work (6).

Bases of calculation and factors of similarity.

The formula given by Newton is still used when calculating the resistance. If F is the maximum surface exposed to the current of air (cross section) in m², v the relative speed between the air and the vehicle in metres per second, ρ the specific mass of the air in kgr. $\overline{\text{sec.}}^{2}/\text{m.}^{4}$, q the pressure of impact in kgr. per m³ or millimetres of water, and c_w a coefficient, the resistance of the air W (in kgr.) is :

$$\mathrm{W} = c_w\, \rho\, \frac{v^2}{2}\, \mathrm{F} = c_w\, q\, \mathrm{F} = q\, \mathrm{F}_{\acute{e}qu} \quad . \; . \; (1)$$

The quantity $c_w\, \mathrm{F} = \mathrm{F}^{\acute{e}}_{qu}$ has generally been used by railways recently; it should be noted, however, that this equivalent surface is simply a comparative value. It must not be looked upon as a plane surface offering equal resistance to the air, as is sometimes done when it is thought with NEWTON that a surface attacked along the normal by the wind has for all shapes the resistance coefficient $c_w = 1$.

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(3) M. Reiner, *Naturwiss.*, vol. 21 (1933), page 294.

(4) A. Frank, *Z.V.D.I.*, vol. 50 (1906), page 593.

(5) In this connection should be mentioned especially F. von Loessl: Die Luftwiderstandsgesetze, der Fall durch die Luft und der Vogelflug (The laws of air resistance, of bodies falling though the air, and of the flight of birds), Vienna, 1896. By quite imperfect test methods, he arrived at a most peculiar theory of the resistance of the atmosphere (theory of the angle of impact) which unfortunately was widely accepted and caused much confusion.

(6) C. Pirath, *Verkehrstechnische Woche*, vol. 23 (1929), page 164.

The coefficient c_w is a number without dimensions; it depends on the form of the body, on the nature of its surface, and on the Reynolds number. The latter is given by $Re = d.v/\nu$ in which d is a characteristic measurement of length for a given geometrical form, v the speed, and ν the kinematic viscosity of the medium in question. For air of 760 mm. of mercury and 20° C., we have, in round numbers, $\nu = 0.15$ cm²/sec. or 0.000015 m²/sec. The surface F and the impact pressure q are definitely fixed by the dimensions and the speed of the vehicle and of the wind, as well as by the atmospheric conditions, and can be calculated easily, so that the whole difficulty of the resistance of the air lies in ascertaining the coefficient c_w. The only method available today, by which to arrive at its value, is by full-size tests, or by tests with models based on the mechanics of similarity. Figure 1 shows the general arrangements of such a trial with models.

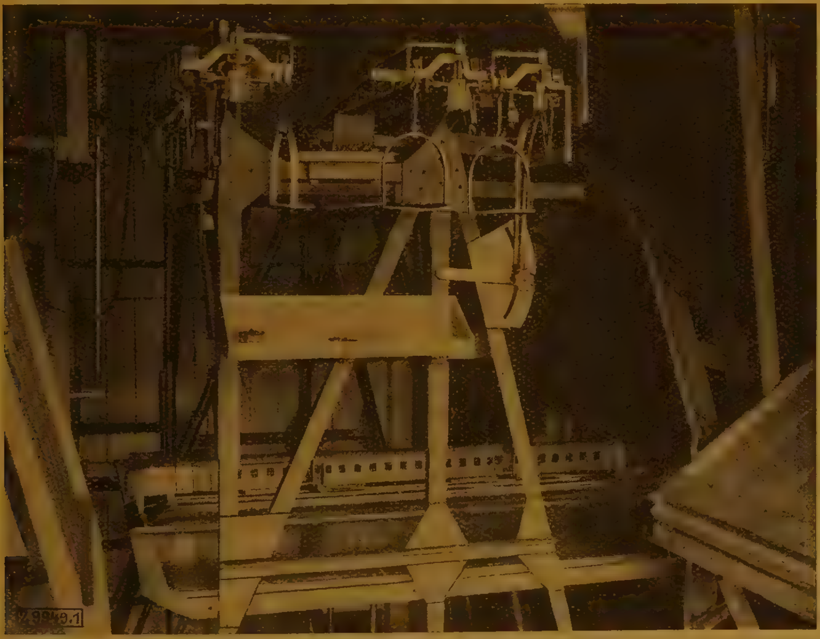

Fig. 1. — General layout of the equipment for measuring the resistance of models in the wind flume.

Model complete with drop lights, ventilators, etc.

Object of trials with models.

The theory of mechanical similarity teaches that two bodies will have the same value of c_w when, besides being geometrically similar, the lines of flow are also alike so that there is, therefore, dynamical similarity. The latter case occurs when the ratio between the frictional forces and the inertia forces is everywhere the same, which leads to the condition that Re is the same (7).

Consequently, the resistance constant can be determined exactly by small-scale model tests when Re can be given the same value as for the full size. With the usual wind flume this condition would be fulfilled were the wind speed to increase in proportion to the reduction of the dimensions of the model. For a 1/20th model, the wind speed would have to be 660 m. (1968 1/2 feet) per sec. to correspond to 30 m./sec. = 108 km. (67.1 miles) an hour with the full-size vehicle. If no departure were made from this rule, we should soon find ourselves amongst speeds exceeding those of sound, when the mechanics of similarity are no longer applicable in the above way.

When dealing with aircraft and railway vehicles especially, it is almost always impossible to get a high enough value of Re, and therefore dynamic similarity. In principle, it is possible to carry the trials further in the pressure air flume, or by towing tests in water (8) when the viscosity is some fifteen times less. This method, however, has its own and greater difficulties. Pressure wind flumes are extremely costly to build and operate; there are at present only two such wind flumes in existence.

Difficulties of tests with models.

The resistance coefficient must, therefore, be calculated for values of Re lower than those obtained in service, so that a few words must be said on the dependence of the values of c_w on Re. In the case of bodies of angular shape or with projections there is little such dependence. The air resistance then consists chiefly of the resistance known as *form resistance* and increases almost exactly as v^2.

When, on the other hand, large surfaces are exposed to the air in the direction of their movement, the *frictional resistance* is the one which comes into action. The constant c_w then diminishes as Re increases. The limit is represented by a plate which meets the air at right angles to its plane; if at very low speeds the current is composed of parallel layers of air, c_w falls in the ratio of $1 : \sqrt{Re}$. W, therefore, only increases with the power 1.5 of v. If the air movement be turbulent, it increases with the power of 1.8. The resultant indices for the speed always lie between 1.8 (simple frictional resistance with turbulent current) and 2 (simple resistance of form), for the resistance in practical cases.

Critical behaviour of c_w.

In 1912, Eiffel called attention to the peculiar behaviour of the resistance corresponding to certain values of Re, this behaviour being explained by Prandtl in 1914. Attention must be called to this irregular behaviour as it greatly affects the question of trials with models. Taking a sphere, for example, we reproduce first of all (fig. 2), above Re, the coefficient c_w. In addition, for a given sphere (150 mm. in diameter), the air resistance is shown above the speed. In the interval Re = 200 000 to 400 000, the curves are most irregular. We have no space here to study the physical reason for this « critical » behaviour (7).

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(7) See, for example, L. Prandtl and O. G. Tietjens : « Hydro- und Aeromechanik », vol. 2, Berlin, 1929; also W. Wien and F. Harms : « Handbuch der Experimentalphysik » (Experimental physics handbook), vol. IV, part 2, Leipzig, 1932.

(8) Professor Föttinger has suggested a method in which the waves are eliminated by plates resting on the water. The models float and roll with the wheels upwards under the plates through which the arm of the weighing machine passes so as to not to interfere with taking the measurements.

This fact, demonstrated here with a sphere, is also found to a more or less pronounced extent with bodies of other shapes. Above the critical region, the dependence on Re is generally very slight so that in this area the law of the resistance being proportional to the square of the speed again applies as a first approximation. The following conclusions can therefore be drawn :

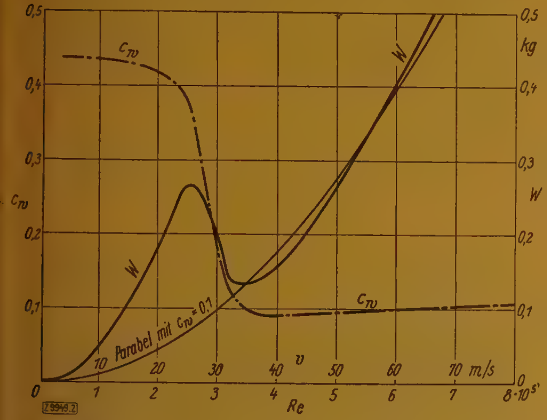

Fig. 2. — Air resistance W of a 150-mm. diameter sphere for air of specific mass $\rho = 1/8$ and a resistance coefficient c_w (according to *Flachsbarth*).

Note: Parabel mit... = Parabola with...

1. The tests must be made in the supercritical region if the actual case lies in a supercritical position;

2. With complicated models such as, for example of locomotives, details of small size, such as projections on the boiler, parts of the motion, and sometimes the chimney, may fall in the infracritical zone, whereas in the actual full-size machine the current is supercritical. If the model is a faithful geometrical image of the actual machine, the values of c_w obtained are too great and the resistance for the actual vehicle will be too high.

Earlier tests.

Until the most recent tests, these facts were not always taken into account. LEBOUCHER investigated the form of rail motor coaches (9) which can fall entirely in the critical zone, as ROY (10) had already pointed out. In addition, LEBOUCHER only carried out his tests at the single speed of 28 m. (91.8 feet) per second = 101 km. (62.8 miles) per hour, that is to say for a single value of Re. It was consequently quite impossible to recognise any irregularity in the resistance coefficient, should such irregularity occur. The curves reproduced on pages 12 and 13 of his article (9) are simply parabolas passing through this single point, and are not curves established from test results.

ROY, probably through the influence of these doubtful tests, came to the conclusion that useful tests on models cannot be made in the case of railway vehicles or coaches, which, in the opinion of other investigators and to our own mind, is far from correct.

ROY calls particular attention to the fact mentioned above in (2) that perfect geometrical similarity of the model gives rise to errors when applying the results to the full-size vehicle (11). While this is undoubtedly true, reliable values can nonetheless be obtained even in this case. In this event, the details which may be expected on the model to be in an infracritical current should be replaced by smaller bodies or be made another shape, which in the model will give the same relative resistance without essentially changing the form of the current. As a rule, special tests have to be made for this purpose.

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(9) LEBOUCHER, *Revue Générale des Chemins de fer*, vol. 51 (1932), 2nd half year, page 3, and *Bulletin of the Railway Congress*, February 1933, p. 219.

(10) ROY, *Revue Générale des Chemins de fer*, vol. 52 (1933), 1st half year, page 3, and *Bulletin of the Railway Congress*, August 1933, page 738.

(11) The same question has also been dealt with by O. G. TIETJENS and K. C. RIPLEY, *Trans. Amer. Soc. Mech. Eng.*, vol. 54 (1932), A.P.M. 23, p. 235, and by F. C. JOHANSON, *Engineer*, vol. 145 (1928), page 146.

For example, when making the tests on models of vehicles described further on, we replaced the ventilators by simple cylindrical bodies (fig. 1). It would have cost too much to copy the Wendler ventilator correctly and the resistance coefficients would have been too high. The bogies too, used in the tests, are very rough and ready copies of the real ones. In any case, perfectly correct and consequently very expensive models, such as for example that of the Canadian National Railways (12), may be described, from the point of view of experimental technology, as useless and even as likely to defeat the desired end. For some decades, in practical experimental work in connection with marine and aeronautical construction, such faithful reproductions have not been used, good results still being obtained. Be this as it may, careful tests with models should be made, taking into account the extent these elements affect the total resistance.

Special features in trials on railway vehicles.

In addition to the above conditions governing the value of tests on models, based on the critical phenomena, we have just dealt with, we have to give sufficient weight to certain ratios of similarity between the vehicle and the model, and this causes difficulties when testing railway vehicle models. In the wind flume, the model is stationary and is subject to the wind driven through the flume, whereas under actual conditions the train is running and the surrounding atmosphere is stationary or has only a slight motion. Consequently, the tests on the model represent an inversion of the true conditions. For there to be at least similarity, the wheels should turn and a reproduction of the track should advance at a speed corresponding to that of the train. This ideal test with a model is very difficult to carry out as the wind speed in the flume reaches or exceeds 60 m. (197 feet) per second.

Different methods of carrying out the tests.

So far models have been suspended in the wind flume in the following ways :

1. Simple hook-up of the model in the free air current without any reproduction of the permanent way (12) ;
2. Use of a belt which travels under the model (11);
3. Addition of a fixed plate representing the ground ;
4. Use of double models (13) ;
5. Goss's experimental plant (14).

These different systems call for the following remarks :

1. This arrangement in no way corresponds to the actual case, as the air can escape on all sides. The influence of the ground has, however, been determined separately in the case in question.

2. This would undoubtedly be the best method if the belt could be made to advance with perfect regularity. This condition does not, however, appear to

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(12) *The Engineer*, vol. 155 (1933), page 385; H. Nordmann, *Z.V.D.I.* vol. 77 (1933), p. 984.

(13) Double models, the object of which is to eliminate frictional limiting surfaces, were probably first suggested by Prof. Föttinger in 1903 when investigating ship models, and have been largely used recently in tank tests on boats to analyse the resistances. See *Jb. schiffbautechn. Ges.*, 1924, page 296.

(14) F. W. Goss, *Engineer*, vol. 86 (1898), page 164.

be possible at high speeds. Any flapping of the belt disturbs the current of air acting on the model ; the return part of the belt is the one liable to run irregularly. No results of tests with this arrangement have been published.

3. As in this case the reproduction of the ground does not move relatively to the model, we may expect to find differences in similarity near the ground. However, if the test is carried out carefully and the length of the model is reasonable, it is always possible to get a sufficiently uniform distribution of the air speed above the plate. If, moreover, as in our tests, the plate is covered with a reproduction of the raised ballast (fig. 3), a marked reduction of speed is only observed near the head of the rail. Consequently, the whole of the main elements composing the air resistance are situated in this normal speed zone.

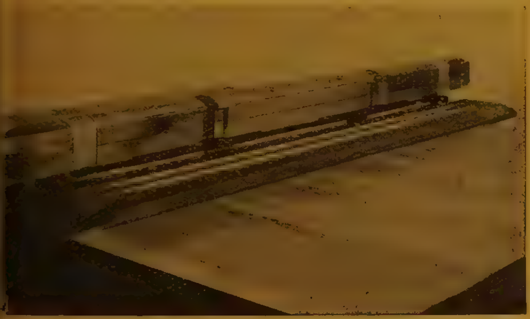

Fig. 3. — Plate with smooth model, no drop lights, ventilators, etc.
The ballast is reproduced on the plate and projects above it.

4. The use of two models with the wheels facing (method of images) enables us to get a current closely reproducing actual conditions. Turbulence, stronger than that experienced in actual practice, can be set up about the wheels through the absence of a real plane. Then too, the process is much more costly owing to the double models.

5. Goss's tests must be mentioned by themselves, as for many years they were the only wind flume tests on the atmospheric resistance of railway vehicles and have been taken into account in recent tests. These tests were carried out on trains of models of as many as 25 vehicles in a wind flume measuring 50 cm. (19 11/16 inches) on each side and 8.20 m. (26 ft. 11 in.) long over all, with wind speeds of up to 65 m. (213.2 feet) per second. Our present knowledge forces us to qualify such an arrangement as likely to give questionable results. Goss's wind flume was a *long tube* and, to some extent, may be likened to a tunnel in which a standing train is subject to the action of wind coming from the outside. The influence of the tunnel walls is very great and gives rise to a current entirely different from that affecting a train running through free air. The results obtained by Goss, therefore, require verification and if this be found necessary, to be corrected by the results of tests based on more precise and more complete theories than are available today.

Consequently the plate and the double model are the only practical simple arrangements at our disposal today. Only experience will show which is the better. Generally speaking there is a tendency to consider the second, the double-model method, as the better. In our tests, however, in which the influence of the end face was eliminated by fixed pieces, the results obtained with the double-model were very little better. LEBOUCHER's conclusions on this method are correct, it is true, but any numerical proof of the errors recorded relatively to actual values has not been given for either the plate or the double model.

Influence of rotating parts.

ROY, in his article, called attention to the additional resistances, and in particular to the « fan » resistance which cannot be ignored, produced by the moving parts and especially by the wheels. Because of this, the air current alters with a model all parts of which are stationary. It is also stated that the resultant of all the aerodynamical forces exerts on the vehicles, especially when there is a cross wind, an additional force, which can modify the flange and journal friction and, therefore, affects the rolling resistance which varies with the weight. We do not know, however, how serious these forces are. Seeing that they are of secondary importance (15) no more time will be devoted to them, as we are not dealing with the comparative values of the atmospheric resistance.

Roy has given a method for ascertaining the total resistance and its component resistances. This may be called « running tests with models » as it consists in ascertaining the air and rolling resistance on models of trains fitted with measuring devices.

The following may be taken as summarising all there is to say on tests on models in wind flumes : « Trials on models generally give values lower than the Reynolds number for the full-size machine. If, however, conclusions may be drawn from these studies, which appear to give higher Reynolds numbers, this is largely because in many cases the influence of the Reynolds number is so small. The values obtained from a model cannot, however, be transposed directly and much experience is required to know when this transposition is allowable and when it is unreliable. Comparative measurements made from time to time with full- size vehicles as and when possible are therefore a necessary complement to tests on models (16).

Test on models and running test.

The comparison we have just made is usually made on railways by *running tests,* which always produce definite results in the eyes of the engineer, as all the influences occurring in service are taken into consideration. The tests, however, themselves are very difficult to carry out as regards ascertaining the air resistance (17).

The following are the advantages of tests with models over running tests :

1. The test programme drawn up on proper bases is followed faithfully ; the trial takes place under uniform speed and air conditions ;
2. The resistance is measured with very sensitive weighing machines which are not damped in any way ;
3. The models can be altered quickly;
4. The cost of the tests as a whole is much smaller ;
5. Numerical values are obtained very soon after completing the preparatory work and the actual test ;
6. The results may be used easily and safely.

As regards the last point, in running trials the total resistance is always measured, although it is difficult to do so exactly, owing to the conditions on the line. This, however, is possible, with the facilities now available. On the other hand, no one has succeeded in separating the rolling and the air resistances, as the results upon which the different train resistance formulæ are based still differ too widely.

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(15) The tests made at Göttingen by C. Pirath on a truck on rollers to ascertain the force required to move a pair of wheels transversely confirm this point of view.

(16) W. Wien and F. Harms, *Handb. der Experimentalphysik* (Experimental physics handbook), vol IV, 2nd part, Leipzig, 1932, page 113*f* . The test mentioned above deals in particular with the possible critical zones with sudden changes of the resistance coefficients.

(17) F. Sauthoff : « Die Bewegungswiderstände der Eisenbahnwagen unter besonderer Berücksichtigung der neueren Versuche der Deutschen Reichsbahn » (The resistance of railway vehicles to forward motion and the recent Reichsbahn tests). Diss. T. H., Berlin, 1933, p. 3. Other contributions are also included.

Nevertheless, we would not like to suggest that running tests are useless. First of all, the test on a model in the wind flume is only used to give the *air resistance,* but it is, therefore, doubtless more useful than the *roller stand* in determining the *resistance to motion.* Owing to the condition of the track, the rolling resistance can only be ascertainned sufficiently accurately by running tests ; in the case of the air resistance too there are still factors which cannot be cleared up so well as by running trials with actual trains.

The question of most importance, after all, is : How does the air resistance increase with the number of vehicles ? The air current changes from coach to coach. As the length of the train increases, the layer entrained by its movement has greater energy. On the other hand, the relative speed immediately against the body sides falls. In calm weather, therefore, with identically alike vehicles, the air current at one of the first vehicles is different from that along one of the last. Now, the extent to which this affects the resistance can only be ascertained primarily by running tests. So far, no great importance has been attached to this condition. We have already said that Goss's wind flume tests ought to be confirmed. In the tubular flume current conditions soon become uniform, that is to say they differ from the actual state of affairs, so that the air resistance due to the air current necessarily is about the same for each vehicle. Neither can Tietjens and Ripley's tests (11) in which the locomotive is first tested alone, then with one or two vehicles, be taken as decisive on the point, although no great difference was found in the atmospheric resistance of the two vehicles.

The trials with models representing the *largest naval units* so far built, on the reduction of the local friction coefficient as the length of the ship increases, make us think that the same action may occur in railway trains. The equivalent area of the isolated railway vehicle would correspond more or less to the local friction coefficient of the ship builder.

Impact pressure.

From equation (1) the impact pressure is $q = \rho\, v^2/2$; when multiplied by the equivalent area in square metres it gives the resistance in kilogrammes. The dependence of the specific mass of the air ρ on the barometric pressure p and the temperature t has not been taken into account in tests so far carried out on the atmospheric resistance of trains, an average figure being used instead. H. Nordmann has already pointed out that this may make the results very unreliable (18). Relatively to the total resistance, the use of a mean value is permissible without serious error for average speeds, as Sauthoff has shown in a calculated example for a speed of 80 km. (50 miles) an hour (19). However, in tests such as those described hereafter, and for high speeds, the exact value of the specific weight of the air must be taken into account. The hydrometric state of the atmosphere also has its influence, although it is slight ; for example, at 30° C. (86° F.) and 100 % humidity, the density is 1.6 % less than that of dry air, whereas at 0° C. (32° F.)

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(18) H. Nordmann, *Glasers Annalen,* vol. III (1932), page 87.

(19) F. Sauthoff, publication referred to above, page 26.

(20) We have prepared abac charts, which we hope to publish later, on a simple method of calculating the impact pressure.

(21) From the records of Potsdam Meteorological Observatory. The first example was kindly sent us by Professor Schwalbe, of the Berlin Meteorological Institute; the second was selected haphazardly. More accurate data on the value and frequency of the changes would be very useful.

and 100 % humidity, it is only 0.23 %. For air of average humidity (60 %), we can use as a good approximation (20):

$$\rho = 0.04714\,\frac{p}{273+t}\ [kgr.\ sec.^{-2}\ m.^{-4}]$$

Besides variations of atmospheric pressure and temperature, the specific mass of the air is subject to other wide fluctuations. In Winter, the maximum values of the atmospheric pressure frequently coincide with minimum temperatures, and inversely, so that the specific mass fluctuates between very wide limits. On the 23rd January 1907, at Potsdam, for example, the specific mass of the air was $\rho = 0.1451$. On the 20th February, 1907, that is just four weeks later $\rho = 0.1217$. On the 16th March, 1928, $\rho = 0.1371$ was recorded and on the 31st March, 1928, $\rho = 0.1192$ (21). These figures show that ρ can vary within a short time, at the same place, between wide limits, especially in Winter. In Summer, the atmospheric pressure and temperature correspond more closely; nonetheless, in our countries the specific mass of the air can vary by 30 % and more in the course of a year. The limits become still wider if we take into account the reduction of pressure due to increased altitude.

Generally speaking, the average value $\rho = 1/8$ is close enough for calculating the total resistance. When, however, running trials are being made to obtain *comparative values* and to arrive at, for example, the effect of alterations in the designs of vehicles, the exact specific mass of the air must be taken into account when calculating the atmospheric resistance, owing to the very slight differences in tractive resistance involved.

As there is always a certain lapse of time between two such tests owing to the alterations to be made, the atmospheric conditions may be expected to be different. A better design might thus be considered as less good as the result of a trial properly carried out in all other respects, and vice versa.

A classic example of this kind is to be found in the trials made by the *High-Speed Electric Railway Investigation Company* on the Marienfelde-Zossen line in 1901 and 1902 (22). The value of the difference between the impact pressure and that inside the vehicle, in 1901, was found to be $P = 0.0054\ v^2$ kgr./m², and in 1902 $P = 0.0052\ v^2$ kgr./m². This latter value is the one usually taken as being correct.

Most probably, the difference is due entirely to a different specific mass of the air; the 1901 tests were made at the end of November, and those of 1902 towards the middle of October. A close study of the way these results were obtained (23) and at the same time of the records of the Meteorological Institute of Berlin and Potsdam shows that there can be hardly any doubt about this point.

Our own tests.

An investigation we made in July, 1932 (24), for Messrs. Borsig, on the atmospheric resistance of locomotives led us to carry out measurements we had had in mind for many years, on the effect of the design of the vehicles. By making use of part of the locomotive testing plant we were able to adopt the lay out shown in figs 4, 5 and 6, the resistance at the forward and back ends being eliminated by the fixed end pieces *a* and *b* (figs. 4 and 5). Between these two end pieces a complete vehicle and two half vehicles, connected by protecting plates at the fixed *a* and *b* end pieces to form a single block, are free to oscillate; they are attached in such a way as to leave them some freedom of

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(22) *Z.V.D.I.*, vol. 47 (1903), p. 1793; see Borries, ditto, vol. 48 (1904), p. 949.

(23) Reports of the test runs on the Military Railway (1901 to 1902), Berlin (1902 to 1904).

(24) *Z.V.D.I.*, vol. 77 (1933), p. 510.

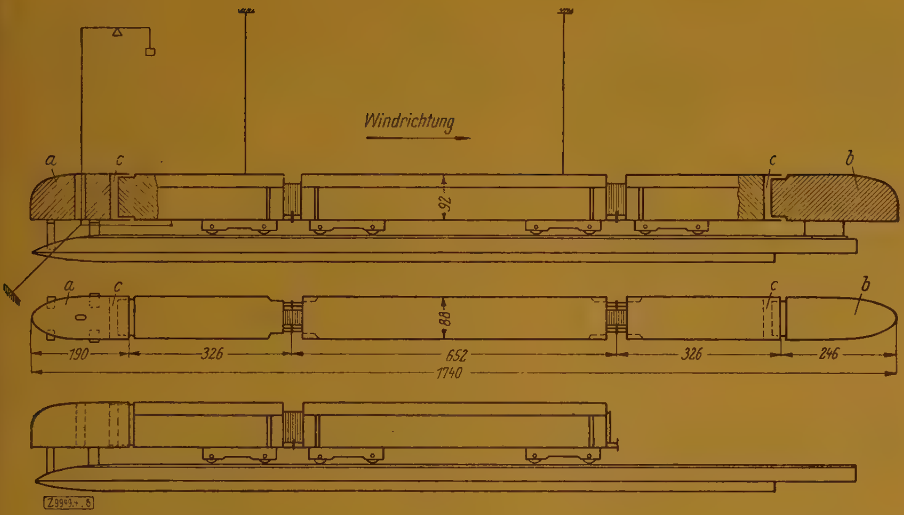

Fig. 4.

Fig. 5.

Fig. 6.

Figs. 4 to 6. — Arrangement of the model as an intermediate vehicle of the train (figs. 4 and 5) and as the rear vehicle (fig. 6).

a and *b* = Fixed connecting pieces. — *c* = Spaces.
Note: Windrichtung = Direction of wind.

movement. Between the vehicles, therefore, there were two passages which had a vital influence on the resistance we were measuring.

It was quite well known beforehand that the motion of the air about a model suspended in this way could not be the same as that, unknown until that time, round actual vehicles. It would perhaps have been better had the head piece *a* been shaped like a locomotive ; if further tests are made this will be done. The profile of the head piece was in this case designed to induce as little extra speed of the air current on the carriage models as possible (25) ; it was not possible to avoid such an increase entirely. The result was a slight depression in the gaps *c*, greater at the leading end than at the trailing, and therefore a force acting against the resistance. On the other hand, the extra speed had the effect of increasing the resistance itself, so that two errors partly cancelled one another. This possible source of error will be avoided in future tests.

In spite of this, very useful results have been obtained from this simple layout, which agree almost exactly with those obtained in running trials.

When the fixed piece *b* and the last half vehicle is removed the equipment is suitable for measuring the increased resistance of the last vehicle (fig. 6) ; in considering the results the absence of the last half vehicle is taken into account. The errors mentioned above can become greater in this case, and the differences wider. It is true that the values for the different types of vehicles tested against one another are always correct since they are all measured under the same conditions.

However, the absolute values of the atmospheric resistances can fall back and probably become too small, and this too is shown by the measurements taken.

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(25) F. Weinig, *Z. angew. Math. Mech.*, vol. 13 (1933), p. 224.

Fig. 16. — For the intermediate vehicle of the train.

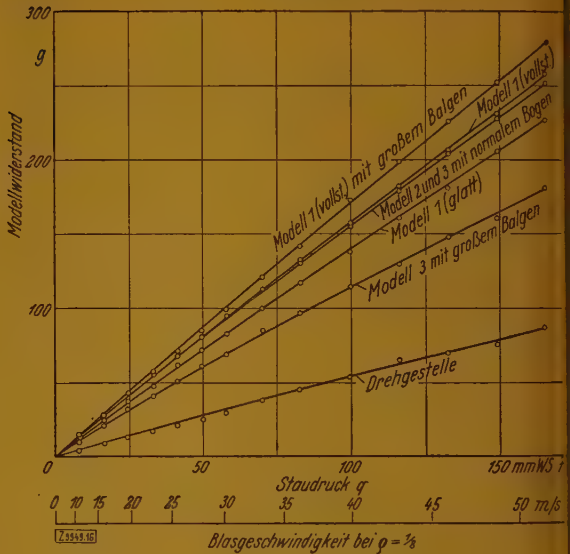
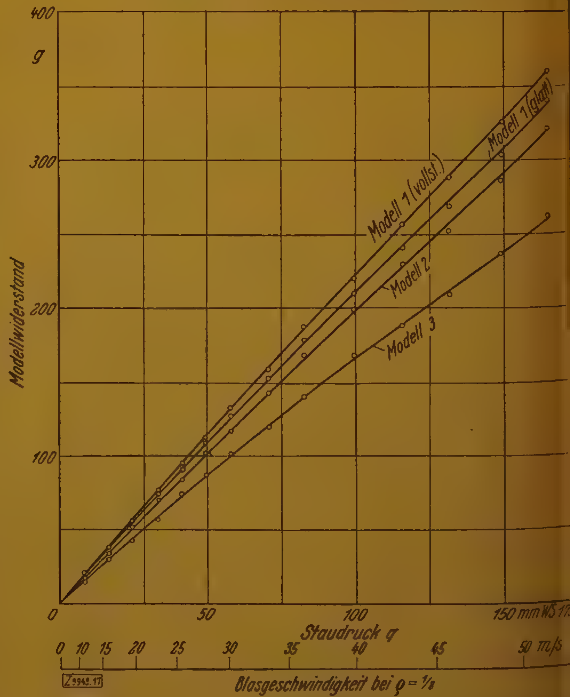


Fig. 17. — For the end vehicle.



Figs. 16 an 17. — Resistances of the models in terms of the impact pressure.

Explanation of German terms:

Modellwiderstand = Resistance of the model. — Blasgeschwindigkeit = Speed of the air current in the flume. — Staudruck = Impact pressure. — Vollst = Complete. — Mit grossem Balgen = With large diaphragm. — Mit normalem Balgen = With standard diaphragm. — Glatt = Smooth. — Drehgestelle = Bogies.

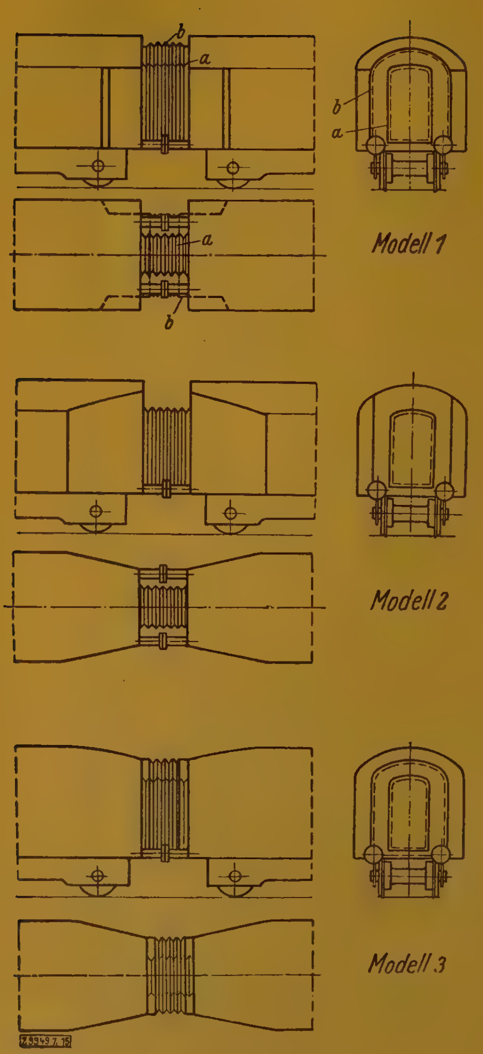


Fig. 7 to 15. — Design of models of the different vehicles at the vestibule ends.

Figs. 7 to 9. — Model 1, of the 1928 type of vehicle: *a*) with standard, and *b*) with large diaphragm.

Figs. 10 to 12. — Model 2, of the 1923/24 type of vehicle.

Figs. 13 to 15. — Model 3, with standard and large diaphragm.

Results of wind flume trials.

The measurements taken were limited to *corridor carriages of recent design*, which can be used for fast services. We measured :

a) the influence of the ends of the vehicles ;

b) the influence of the dimensions of the diaphragms, and

c) the influence of the additional resistance due to windows, ventilators, step boards, etc..., but this latter only for a single type of vehicle.

The models were identical except the body ends, and are shown in figures 7 to 15. The models 1 and 2 are of corridor coaches of the Reichsbahn ; model 1 an all-metal 3rd class carriage, 1928 type, class C 4 ü 28 ; and model 2 a 2nd-class carriage 1923/4 type, class B 4 ü 23/24. These models are to scale ; the third model is not ; it simply represents the body ends of a recent French Nord carriage (26). The models are at present made of wood, without windows, ventilators, doors, etc...

Two diaphragms were tested on each of models 1 and 3, the standard and a large one taken out over the buffers (27) ; the standard diaphragm alone was used with model 2.

We were able to compare the results with those of running trials in the case of model 1 only, by using the results of the extensive tests carried out by the Reichsbahn in 1929 on the resistance of the 1928-type corridor carriages. The smooth wooden models showed, in the wind flume, a resistance some 16 % lower in value to that found by Nocon in these running trials (28). When the model was completed by window recesses made in it, and the ventilators, step boards, and battery boxes fitted, the resistance was still 5 % less than that found by Nocon. When we remember that the bogies of the actual vehicle are

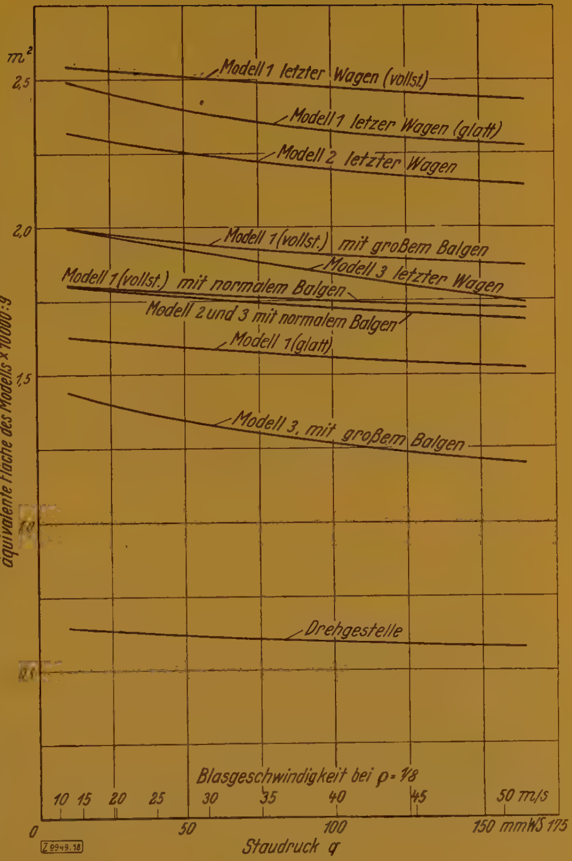


Fig. 18. — Equivalent surfaces transposed to the actual vehicle by calculation, from the results shown in figs. 16 and 17.

Note : Aquivalente Fläche des Modells = Equivalent surface of the model. — Letzter Wagen = Rear vehicle.

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(26) Vallancien, *Org. Fortschr. Eisenbahnwesens*, vol. 87 (1932), p. 243. These vehicles are very striking owing to their smooth exterior.

(27) H. Nordmann, *Glasers Annalen*, vol. 111 (1932), p. 87, and *Organ Fortschr. Eisenbahnwesens*, vol. 87 (1932), p. 39.

(28) E. Nocon, *Glasers Annalen*, vol. 108 (1931), p. 99.

complicated, that there is a lighting dynamo and other fittings, which tend to increase the resistance, the agreement between the results of the running trials and those on the model may be said to be very close. The differences obtained with the different models may, therefore, be applied to the full-size vehicle.

In order to ascertain the effect of the bogie, the body alone is tested. This method is not entirely correct, as it sets up a quite different current under the model ; the result, however, gives a reference point when ascertaining the magnitude of the resistance.

The resistances obtained with the model are shown, on figure 16, in terms of the impact pressure for the intermediate vehicle of the train. Figure 17 gives them for the rear vehicle. They have been reproduced to show the accuracy of the measurements. Figure 18 shows the equivalent areas converted for the full-size model ; this has been done so that the results can be better appreciated. We must, however, be careful not to conclude that the actual equivalent areas of the full-size coach alter to this extent for the speeds and impact pressures in question.

For this reason, table 1 gives once again the equivalent areas $F_{équ}$, and the relative resistances recorded at each moment in the wind flume, in terms of the resistance of the carriage (in heavy type) used as a comparison, and finally the horse power used for four higher ranges of speed.

TABLE I.

Equivalent surfaces $F_{équ}$, comparative values of the resistances, and power required for a vehicle at different speeds (in calm weather).

	Type and arrangement.	Diaphragm.	*$F_{équ}$* m^2 *(sq. feet).*	Comparative values.				Horse power required at the speed of			
								90 km /h. (*56 m.p.h.*)	120 km /h. (*75 m.p.h.*)	150 km./h. (*93 m.p.h*)	180 km./h. (*112 m.p.h.*)
As rear vehicle.	Model 1, complete (*) . .	Standard	2.44 (*26.26*)	1.41	—	—	—	31.7	75.5	147	254
	» 1, smooth . . .	»	2.28 (*24.54*)	—	1.49	—	—	29.6	70.5	137	238
	» 2 » . . .	»	2.15 (*23 14*)	—	—	1.27	—	27.9	66.5	130	224
	» 3 » . . .	Large	1.75 (*18.84*)	—	—	—	1.46	22.8	54.1	105	182
As intermediate vehicle.	Model 1, complete . . .	Large	1.88 (*20.24*)	1.09	1.23	—	1.57	24.4	58.2	113	196
	» 1 » . . .	Standard	1.73 (*18.62*)	**1.00**	1.13	—	1.44	22.5	53.5	104	180
	» 1, smooth. . . .	»	1.53 (*16.47*)	0 88	**1.00**	0 91	1.27	19.9	47.4	92.2	159
	Models 2 and 3, smooth (**)	»	1.69 (*18.19*)	—	1.11	**1.00**	1.41	22.0	52.4	102	176
	Model 3, smooth. . . .	Large	1.20 (*12.92*)	0.69	0.79	0.71	**1.00**	15 6	37.1	72.3	125
	Bogies	—	0.58 (*6.24*)	0.34	0 38	0.34	0 48	7.5	18	35	60

*) Complete means : with drop lights, ventilators, etc. Cf. fig. 1. ; « smooth », cf. fig. 3.

**) The resulfs of tests with the two different types were so nearly similar that they have been grouped together here.

This table shows that :

1. the increased resistance of the last vehicle is not a fixed ratio to that of the intermediate vehicles of the train ;

2. greater attention must be given to the designs of the bogies for the reason that in a cross wind the bogie has a much more serious effect than the much « smoother » body, and

3. the best type of vehicle only shows its full value at high speeds, since the power required increases as the cube of the running speed.

It is most important first of all to note that good aerodynamical profiles do not depend alone on the design of the body or on the width of the diaphragm by itself ; the two conditions must be united. In model 3, which gave bad results with the standard diaphragm, the large diaphragm reduced the resistance by 29 %, that is very considerably. On the other hand it increased the air resistance by 9 % on the good design of model 1.

Tests to ascertain the path of the air stream.

The variations in the results is due to the kind of current which forms at the ends of the vehicle. We can get a first idea of these phenomena, at least on the body sides, by towing a model corresponding to the horizontal section of the vehicle in water containing a mixture of powdered lycopoedium and aluminium powder (Ahlborn process). Figures 19 to 26 are snapshots, taken under the same conditions, of the formation of eddies varying within the time. The camera moved with the towed model and recorded, therefore, the relative current and in particular eddies relatively stationary such as would be seen from the train. The eddies in relative motion set up lines which cross one another.

Figure 19, corresponding to model 1 with standard diaphragm, shows that the whole of the space between the carriages is full of eddies, so that the exterior current as it were slips over them as on a roller bearing, without penetrating to any extent into the recesses. Owing to the angular form of the passages, the eddies cannot get back so easily into the outside current as in the case of models 2 and 3 (fig. 20). In the case of the latter, the easy taper of the sides makes it easier for new energy to flow into the whirling mass but also makes it easier for the eddies which have left the main stream to escape back into it. The whirling mass is in all cases more stable in figure 19 than in figure 20.

Against this, with model 1 and large diaphragm (figs. 21 to 23) behind angle *a*, rather a long chain of small eddies is set up more or less all the same size. Theory and experience teach us these chains of eddies are very unstable; the number of eddies which leave at the outgoing side is nearly double that observed with model 1, with a standard diaphragm. Figure 21 shows in the top half that, once the last eddy has been carried away, the current strikes freely against the side *b* of the following vehicle. This particularly serious drawback is largely avoided with model 3 with large diaphram (fig. 24) ; moreover, the eddies set up are much smaller than in figure 21. Figures 22 and 23 show the great changes in the flow of the current.

These snapshots thus allow us to study the nature of the currents ; it must of course be remembered that the photographs only show the momentary state of currents in the horizontal plane, whereas in fact these currents vary periodically and are three-dimensional. They undoubtedly follow a parallel path over the roof.

Finally, figures 25 and 26 show, for the two designs, the conditions of the current on the last vehicle. The exterior currents reunite better in figure 26 which shows, in harmony with the measurements of resistance obtained in

Figs. 19 to 26. — Towing tests in water, made with sections

Figs. 21 to 23. — Model 1 with large diaphragm; development of the current at different moments; the figures show the great variation in the formation of eddies.

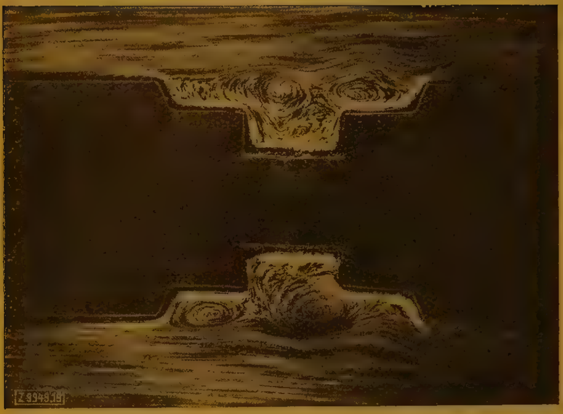

Fig. 19. — Model 1 with standard diaphragm.

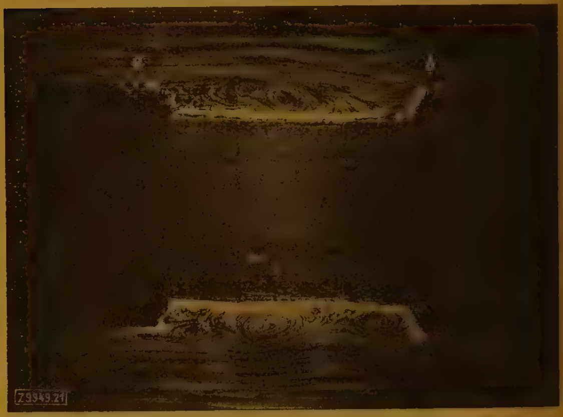

Fig. 21. — The free current strikes against angle *b*.

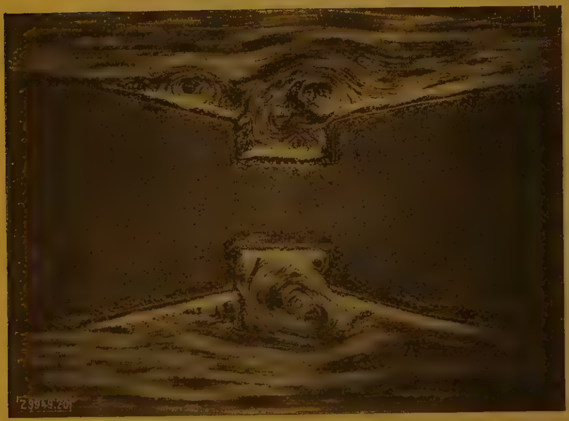

Fig. 20. — Models 2 and 3 with standard diaphragm.

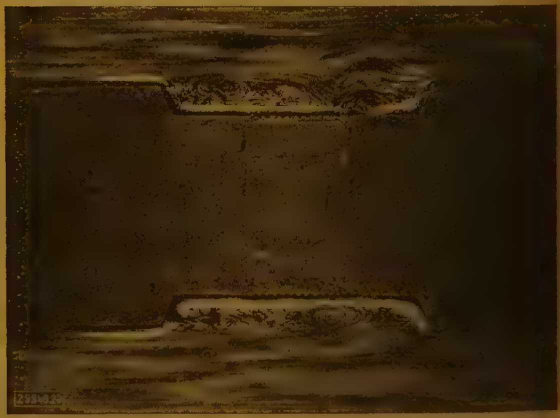

Fig. 22. — Intense formation of eddies in front of *b*.

the wind flume, the superiority of this shape.

Economic importance of the air resistance.

The object of the present note has not been to examine very closely the

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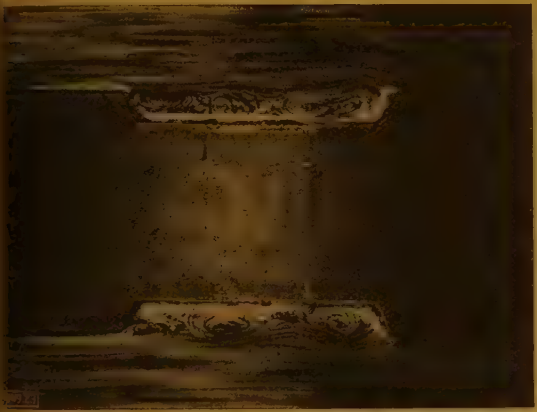
(29) The clear lines on the edges of the models are due to reflections which could not be prevented when the photographs were being taken.

hicle models, to show the behaviour of the current (29).

Figs. 25 and 26. — Current conditions on the last vehicle. — Fig. 25, model 1. — Fig. 26, models 2 and 3.



ig. 23. — Practically uniform distribution of eddies.

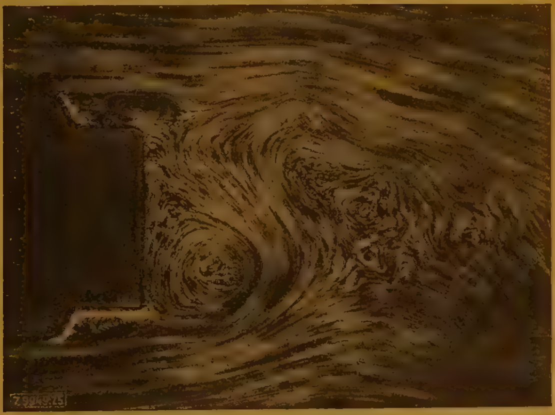


Fig. 25. — Large area of dead water behind the square end of the vehicle.

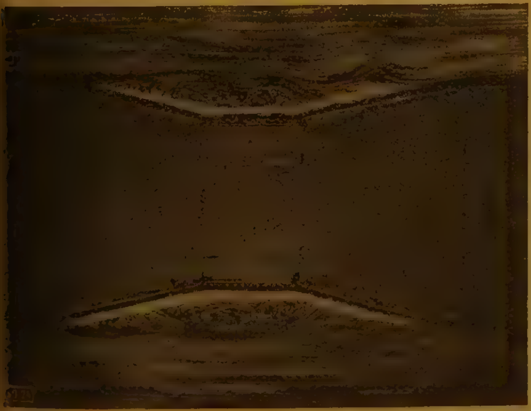


Fig. 24. — Model 3 with large diaphragm.

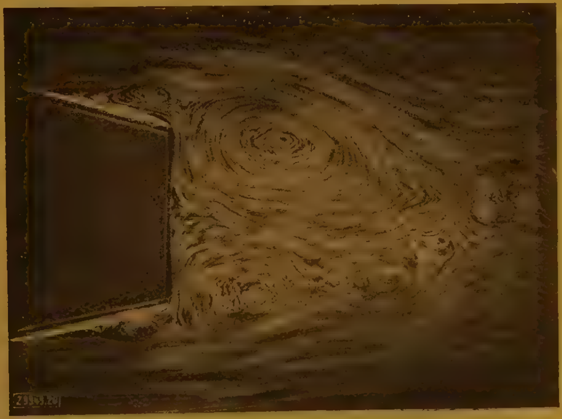


Fig. 26. — Satisfactory current behind the end of a tapered-off vehicle.

economic importance of the air resistance in railway working. To form an idea of the financial aspect of the question, Johansen should be studied as he, after a *cautious* estimate of the conditions, comes to the conclusion that a reduction of 25 % in the air resistance alone would mean an annual saving of £ 50 000 (or in 1928, about one million Rm.) for each of the English group

Companies (30). True, a more accurate calculation of this kind would not be simple even for a long-distance train (such as one running 600 km.=373 miles) if the profile of the line was such as to mean frequent changes in speed. And as a dead calm cannot be expected to be the average condition throughout the year, the influence of the wind would have to be studied, as it is a factor which is both doubtful and complicated. For a great system such as the Reichsbahn, an exact calculation of the total saving would be in any case very tedious.

From the tests in question the atmospheric resistance of model 3 with large diaphragm is about 30 % less than that of the present type of corridor vehicle type C 4 ü 28. This value probably applies to the full-size vehicle, in spite of the simplified form of the model.

The tests carried out in our Institute for the Borsig Lokomotive Works (24) showed a still greater reduction in air resistance as regards the locomotives. For the train as a whole, the reduction in air resistance can exceed the 25 % given by JOHANSEN without it being necessary to adopt shapes very different from those so far in use. With streamlined profiles, better results can, of course, be obtained.

Programme of future trials.

In view of the particular way in which the resistance is set up at the gaps between the vehicles, we propose to carry out a scheme under consideration for some time by Professor FÖTTINGER as a continuation of the previous tests. The object of these further tests is to carry out a methodical investigation into the friction and resistance of bodies of this kind, made up of sections, with special reference to the conditions imposed by the methods of construction used on the railways.

Further tests will be made to find out numerical values in respect of facts of which the railway engineer has been aware for a long time. With the new plant we wish to ascertain the air resistance of open wagons loaded and empty; the figures that have been published on this subject require confirmation. We ought to be able to also find the answers to the question how much the air resistance is increased by open doors on covered wagons and parcels vans.

Much interest is taken in the ventilation of passenger carriages. Numerical data is wanted on the increase in air resistance through opening a window. It is not possible at times to avoid opening the windows whilst the train is in motion, if the vehicle is to be properly ventilated, even in sections only partly occupied. The additional demand on the locomotive would appear to be quite considerable, judging from the trials on open goods wagons, especially at high speeds. The question then arises as to whether a special system of ventilation (32) might not be cheaper and more efficient than by means of drop lights. According to the results of tests quoted earlier on, the ventilators themselves add considerably to the air resistance. The passengers would warmly welcome artificial ventilation with closed windows provided it were adequate, as the vehicles so equipped are more pleasant to travel in.

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We wish to once more convey our deepest gratitude to our respected Mas-

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(30) F. JOHANSEN, article mentioned above. The same question has been dealt by O. G. TIETJENS and K. C. RIPLEY (article quoted above), and in a note by Messrs. Sulzer Brothers, Winterthur, Switzerland, *Schweizerische Bauzeitung*, vol. 102 (1933), p. 287.

(31) Publication of the *Inst. für Tech. Strömungsforschung der T. H.*, Berlin. Pamphlet No. 1 will be issued shortly.

(32) GÜNTHER, *Organ Fortschr. Eisenbahnwesens*, vol. 88 (1933), p. 419, and E. METZELTIN, *Z.V.D.I.*, vol. 77 (1933), p. 1063.

ter, Professor **Föttinger**, who kindly supported us and placed his wind flume at our disposal during the tests ; also to Professor **Nordmann**, V.D.I., for his valuable advice in connection with the drawing up of the present note and the graphical representation of the test results. We are also particularly indebted to our colleagues, Messrs. **Eicke** and **Sydow**, Dipl. Ing., for their kind assistance.

Professor **Medici**, of the Padua Higher Technical School, who remained a whole year in Germany as a Delegate of the Italian Government, in order to study the work of the German Research Centres, repeated on his own account and quite independently, as a guest of our Institute, some of the previous measurements, so as to control our results which, at first sight, appeared really remarkable.

[62 .01 & 669]

Working stresses for high-temperature service [1]

by P. G. Mc VETTY,
Westinghouse Research Laboratories, East Pittsburgh, Pa.

(Mechanical Engineering.)

The problem of the assignment of working stresses for high-temperature service depends primarily upon the interpretation of the results of high-temperature tests. A solution of this problem requires satisfactory service over a reasonable period of time at minimum cost. Progress in high-temperature design demands that any deficiency of data necessary to effect a solution must be met by a courageous interpretation of available information by the metallurgist, the testing engineer, and the designer. The present tendency to shift the whole burden of responsibility for interpretation of test data to the shoulders of the designer is unfair not only to him but also to the material which may be discarded solely as a result of improper interpretation or application.

So many factors affect choice of materials and assignment of working stresses that it is necessary carefully to define the limits of the present discussion. Of the various types of tests which have been used, attention is confined to the long-time tension or creep test for which the largest amount of reliable information has been obtained. This does not prelude the possibility of the displacement of this test by others in the future. For the present, complications introduced by consideration of changes in stress or temperature, by fatigue, impact, corrosion, or other service conditions must be left for later discussion. Applications are restricted to materials which maintain satisfactory ductility throughout their service life. The important question of stability as it may be affected by age hardening, annealing, or other internal changes is a strictly metallurgical problem which cannot be included in the present discussion. It is also necessary to exclude complicated cases such as highly stressed tubes at very high temperatures for which simple tension creep tests may not be a satisfactory basis for working stresses. Within the limits outlined, the assignment of a safe working stress for a ductile material depends upon a knowledge of the relations among the four variables — temperature, stress, deformation, and time.

Two types of high-temperature design problems.

High-temperature design includes two distinct classes of problems dependent upon the aforementioned four variables. One may be represented by a bolt which holds two flanges together at high temperature. The original tightening of the nut applies an initial stress and corresponding initial elastic deformation to the bolt and the material surrounding it. As creep occurs, the total deformation remains essentially constant, while elastic strain is converted into plastic strain or creep with a corresponding decrease in stress. Eventually, leakage at the flange may be expected unless the bolts are retightened or the design is such that a suitable stress is maintained during the service life. This is commonly called the « relaxation problem », consideration of which will be reserved for a later paper.

In the other type of problem, stress and temperature are essentially constant

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[1] Presented at the Annual Meeting, New York, N. Y., December 4 to 8, 1933, of *The American Society of Mechanical Engineers.*

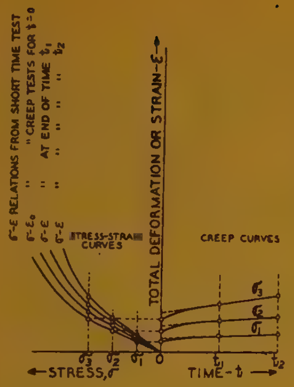

Fig. 1. — Relation between stress-strain and creep curves at constant temperature.

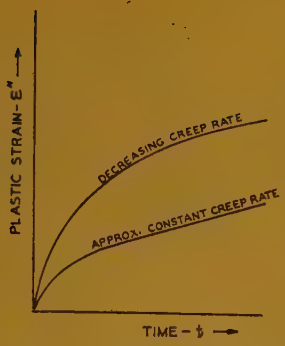

Fig. 2. — Two types of creep curves.

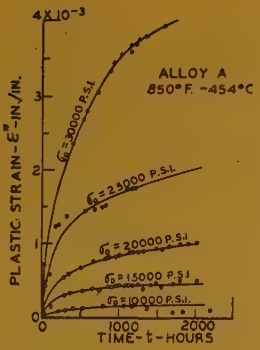

Fig. 3. — Original creep curves.

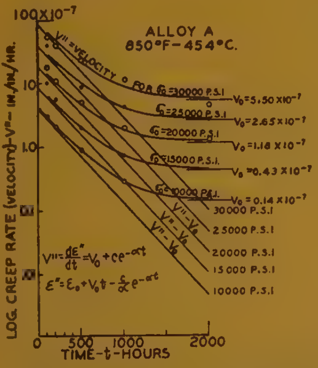

Fig. 4.— Differentiated creep curves from fig. 3.

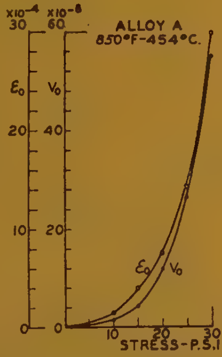

Fig. 5. — Effect of stress on constants E_0 and V_0.

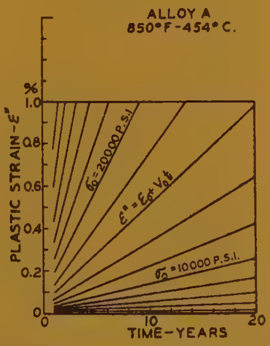

Fig. 6. — Asymptotes of creep curves for constant stress and temperature.

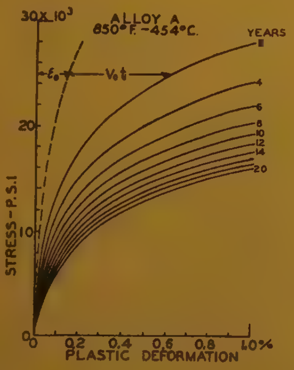

Fig. 7. — Stress-strain-time relations at constant temperature.

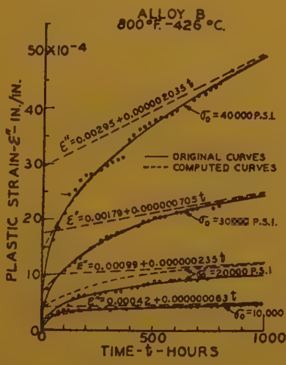

Fig. 8. — Original creep curves. Data from Mr. J. J. Kanter, Crane Co.

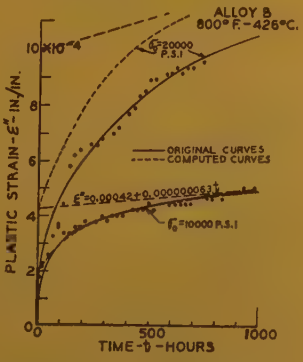

Fig. 9. — Original creep curves. Data from Mr. J. J. Kanter, Crane Co.

Figs. 1 to 9.

(Composition of alloy A : C = 0.115 ; Mn = 0.41 ; P = 0.010 ; S = 0.025 ; Si = 0.155 ; Ni = 0.10 ; Cr = 12.46 %. Composition of alloy B : C = 0.12 ; Mn = 0.56 ; Si = 0.315 ; Cr = 12.23 %.)

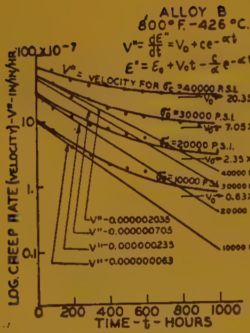

Fig. 10. — Differentiated creep curves from figures 8 and 9.

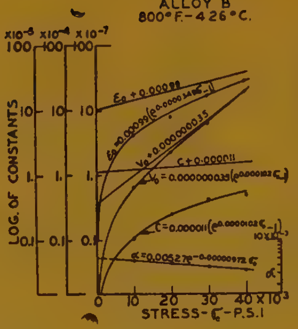

Fig. 11. — Effect of stress on constants of tension creep curves.

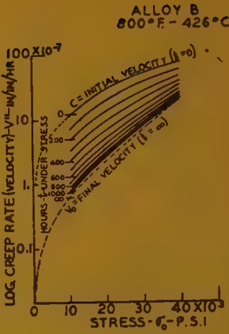

Fig. 12. — Velocity-stress-time relations at constant temperature.

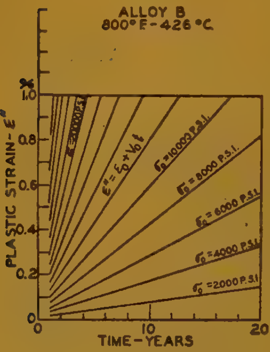

Fig. 13. — Asymptotes of creep curves for constant stress and temperature.

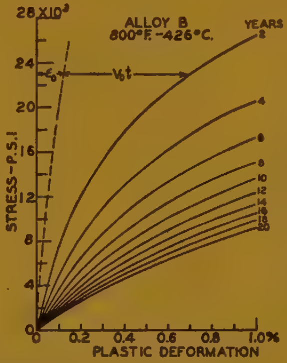

Fig. 14. — Stress-strain-time relations at constant temperature.

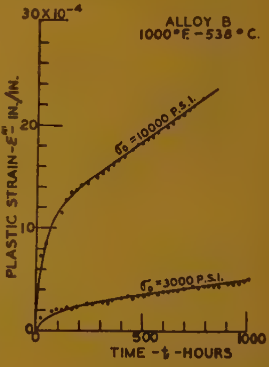

Fig. 15. — Original creep curves. Data from Mr. J. J. Kanter, Crane Co.

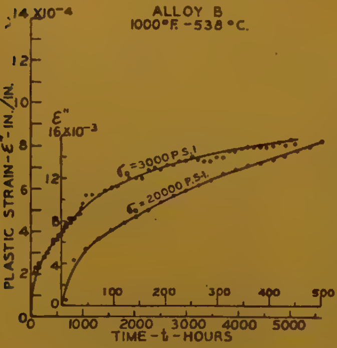

Fig. 16. — Original creep curves. Data from Mr. J. J. Kanter, Crane Co.

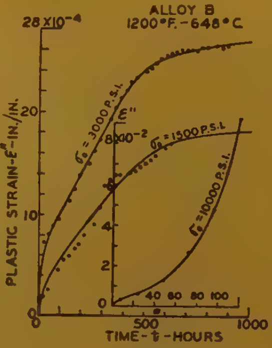

Fig. 17. — Original creep curves. Data from Mr. J. J. Kanter, Crane Co.

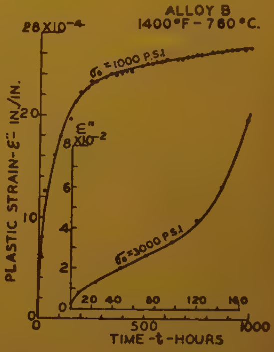

Fig. 18. — Original creep curves. Data from Mr. J. J. Kanter, Crane Co.

Figs. 10 to 18.
(Composition of alloy B: C = 0.12; Mn = 0.56; Si = 0.315; Cr = 12.23 %.)

while deformation or creep varies as a function of time. In the conventional long-time tension or creep tests (2) (3) (4) an attempt is made to simulate these conditions by maintaining constant stress and temperature, while the relations between time and deformation are studied. It is generally agreed that this type of test is the most satisfactory of those which have been commonly used up to the present time for supplying design information based on the relations among the four variables being considered.

Plan of attack on problem of appraising and correlating data is proposed.

In order to appraise and correlate all existing test data so as to make them available in convenient form for design use, it is necessary to reduce them to comparable form with due allowance for the effect of uncontrolled variables. It is the main purpose of this paper to suggest a plan of attack upon this store of undigested information so as to obtain from it the greatest possible amount of use. It is realized fully that more or less arbitrary assumptions are necessary, but this may be preferable to the somewhat chaotic state of existing unrelated test data. Later checks will decide whether they were correct or must be altered.

Among the numerous papers on properties of metals at high temperatures, relatively little has been done to connect creep phenomena with known laws of physics and physical chemistry. Reference may be made to Dr. Nadai's discussions (5) (6) of this phase of the problem because it appears evident that a satisfactory solution depends upon a more perfect understanding of the fundamental laws governing creep phenomena. Important work has been done (7) (8) and experimental investigations now in progress are expected greatly to extend our knowledge in this field. The mention of creep tests under combined stresses indicates the extent of the field of investigation still to be explored before design can proceed with absolute assurance of success.

The following notation is used throughout this paper :

ε = total strain (unit elongation).
$\varepsilon = \varepsilon' + \varepsilon''$
ε' = elastic part of strain ε
$\varepsilon' = \sigma/E$
ε'' = plastic or permanent part of strain ε (creep),
E = modulus of elasticity,
σ = stress (computed for actual cross-sectional area A of bar),
σ_0 = stress (computed for original cross-sectional area A_0 of bar),
t = time,
v = total rate of strain = $d\varepsilon/dt$,
v' = elastic rate of strain which is zero in the case of constant stress considered here,
v'' = plastic rate of strain = $d\varepsilon''/dt$ (creep rate),

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(2) « Creep of Metals at Elevated Temperatures », by P. G. McVetty, *Mechanical Engineering*, vol. 53 (1931), pp. 197-200.

(3) « Factors Affecting Choice of Working Stresses for High-Temperature Service », by P. G. McVetty, *Trans. A.S.M.E.*, 1933, *APM-55-13.*

(4) « Obtaining Reliable Values for Creep of Metals at High-Temperatures », by H. W. Gillet and H. C. Cross, *Metals and Alloys*, July, 1933.

(5) « The Creep of Metals », by A. Nadai, *Trans. A.S.M.E.*, 1933, *APM-55-10*, pp. 61-77.

(6) A. Nadai, in a discussion of a paper entitled « Working Stresses », by C. R. Soderberg, *Trans. A.S.M.E.*, 1933, *APM*-55-16, p. 141.

(7) « Creep of Steel Under Simple and Compound Stresses, and the Use of High Initial Temperature in the Steam Power Plant », by R. W. Bailey, *Trans. Tokio, Japan, Sectional Meeting, World Power Conference*, vol. 3 (1929), pp. 1089-1121. For abstract, see *Engineer*, vol. 148 (1929), pp. 528-9.

(8) « Strength of Materials Subject to Shear at High Temperatures », by F. L. Everett, *Trans. A.S.M.E.*, 1931, *APM-53-10*, p. 117.

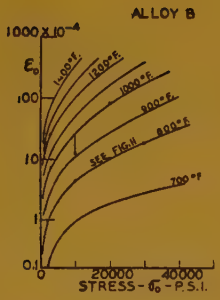

Fig. 19. — Effect of stress on constant-ε_0.

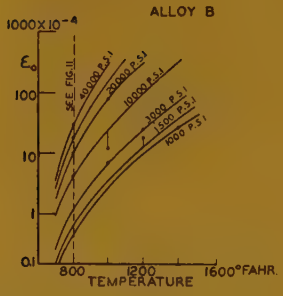

Fig. 20. — Effect of temperature on constant-ε_0.

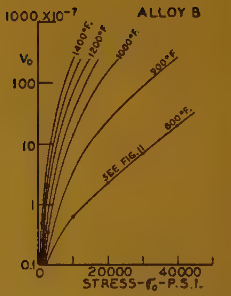

Fig. 21. — Effect of stress on constant-V_0.

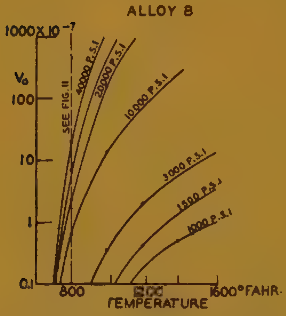

Fig. 22. — Effect of temperature on constant-V_0.

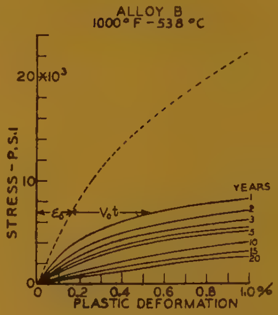

Fig. 23. — Stress-strain-time relations at constant temperature.

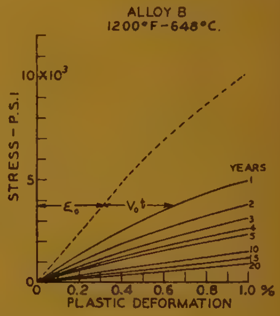

Fig. 24. — Stress-strain-time relations at constant temperature.

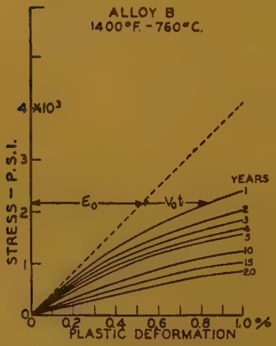

Fig. 25. — Stress-strain-time relations at constant temperature.

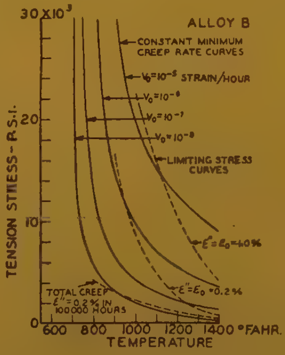

Fig. 26. — Effect of primary creep on stress-temperature relations.

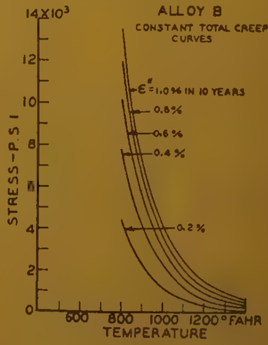

Fig. 27. — Effect of allowable deformation on stress-temperature relations.

Figs. 19 to 27.
(Composition of alloy B : C = 0.12 ; Mn = 0.56 ; Si = 0.315 ; Cr = 12.23 %.)

θ = temperature,

η = viscosity coefficient for pure shear,

ϕ = viscosity coefficient for tension = 3η.

In figure 1 the curves representing short-time and long-time tension tests at a constant elevated temperature have been combined to show the relation between them. This method of representation shows also how the effects of creep during various periods of time may be added to the conventional stress-deformation curve (9) as a means of representing the essential information obtained from a family of creep curves. Being limited in time to the actual duration of the creep tests, it is necessary either to extend the creep tests to periods of time comparable with service life or to extrapolate curves representing relatively short tests. While the practice is open to objections (2), the commonly used straight-line extrapolation of creep curves may be accepted for practical purposes until more complete information as to the true nature of the creep-time curve $\varepsilon = f(t)$ over several years is obtained.

Two types of creep curves.

Figure 2 represents two types of creep curves. In one, the curve follows what is essentially a straight line during a substantial portion of the test. The other shows a continuously decreasing creep rate throughout the test. The direct straight-line extrapolation of the first is the best available procedure but the second offers more difficulty. The use of a final tangent to the second type of curve frequently leads to unduly conservative estimates of deformation and of working stresses. It will be shown that an asymptote to this type of curve is preferable for the purpose of extrapolation and that it offers the advantage of a reduced testing time. In either case, the possibility of an inflection (2) within the service life must be excluded just as it is when a definite creep rate is associated with each combination of stress and temperature (10).

Figure 3 represents a family of creep curves of the latter type, the tests all being made at 850° F. (454° C.) using equipment and methods previously described (10) (11) (12), as applied to a forged and heat-treated stainless iron furnished by N. L. Mochel. To interpret such a family of curves, both interpolation and extrapolation are necessary; the former in respect to stress and the latter in respect to time. The interpolation between zero stress and the lowest stress actually tested is fully as important as the extrapolation from the duration of the test to a time representing service life.

Studies of families of curves similar to figure 3 have shown that, at constant stress and temperature, in the first portion of the creep curves the excess of creep velocity above a certain minimum creep rate v_0 decreases very nearly geometrically as time t increases arithmetically. This suggests an exponential relation between creep velocity v'' and time t of the form

$$v'' - v_0 = ce^{-\alpha t} \quad . \quad . \quad . \quad . \quad (1)$$

in which v_0 is a constant and $v'' = d\varepsilon''/dt$ (the slope of the creep curve). Assuming further that the parameters v_0, c, and α depend only upon the stress σ at constant temperature θ, we may assume that they remain constant during a test at constant stress and temperature.

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(9) « Testing of Materials at Elevated Temperatures », by P. G. McVetty, *Proc. A.S.T.M.*, vol. 28 (1928), part 2, p. 69.

(10) Report of Committee A-10, « Safe Working Stresses at Elevated Temperatures », *Proc. A.S.T.M.*, vol. 30 (1930), part 1, Appendix, plates 5, 7, and 9.

(11) « The Tensile Properties of Metals at High Temperatures », by T. D. Lynch, N. L. Mochel, and P. G. McVetty, *Proc. A.S.T.M.*, vol. 25 (1925), part 2, pp. 5-52.

(12) P. G. McVetty in a discussion of a paper by H. J. French, entitled « Methods of Test in Relation to Flow of Steels at Various Temperatures », *Proc. A.S.T.M.*, vol. 26 (1926), part 2, pp. 26-30.

Equation of creep curves.

By integration of equation [1] with respect to the time t, an equation representing the original creep curve may be written :

$$\varepsilon'' = \varepsilon_0 + v_0 t - \frac{c}{\alpha} e^{-\alpha t} . \quad . \quad . \quad (2)$$

It is, of course, impossible to say that this is the equation for the creep curve, but application to many tests of different materials has shown that such a curve with properly chosen constants closely follows the original data during periods of time for which creep tests have been conducted. The assumption that the creep curve for constant stress and temperature is one having a straight-line asymptote is equivalent to an assumption of viscous flow in the second stage of creep. If the metal is structurally stable, it is reasonable to assume that, below certain upper limits for stress and temperature, the viscosity coefficient η for pure shear remains for a constant stress σ practically constant so that the creep rate v'' approaches a minimum value v_0 which may be considered also to remain practically constant over long periods of time such as the service life of the material. The validity of this assumption may be verified by a study of the relation between creep velocity and plastic strain for several stresses at the same temperature (¹³). It is impossible within the scope of this paper to discuss more fully this phase of the problem, but the only reasonable conclusion is that the time at or near the minimum creep rate for low stresses must be extremely long. If it is necessary to justify extrapolation of the creep curve in respect to time it may be done by reference to the $v'' - \varepsilon''$ relations.

Space limitations prevent a discussion of the various possible methods of determining the constants in equations [1] and [2]. One approach is illustrated in figure 4 in which the points shown were obtained by differentiation of the curves in figure 3 at the end of five different periods of time while the curves represent equation [1] and show means of obtaining the constants v_0, c, and α. The value of ε_0 in equation [2] is obtained by substitution of corresponding known values of ε'' and t. Theoretically, ε_0 should be equal to c/α when $t = 0$. In some case, this gives undue importance to the first few hours of the test and the resulting curve does not follow the points as well as that obtained by the method suggested.

Predicting deformations greater than those of the creep test.

Any attempt to predict deformations in times greater than those of the creep test may be based on the asympote of equation [2] which may be written :

$$\varepsilon'' = \varepsilon_0 + v_0 t \quad . \quad . \quad . \quad . \quad (3)$$

in which the constants are known for the particular combinations of stress and temperature for which tests have been made. In the simpler case in which the creep curve itself follows a straight line capable of direct extrapolation, a similar equation may be written and the constants determined from the intercept and slope of the curve. In this way, tests for various periods of time may be extrapolated and compared under more favorable conditions than would result from the use of the final tangent. Such data are, however, limited to stresses for which tests have been conducted.

If the reasonable assumption is made that both ε_0 and v_0 equal zero when the stress is zero it is possible to plot the values of these constants as functions of stress as shown in figure 5. Taking

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(¹³) The author is indebted to R. BEEUWKES, Jr., of the Westinghouse Research Laboratories, for permission to refer to his excellent investigation of these relations, the results of which have not yet been published.

values of ε_0 and v_0 from these curves, the extrapolated creep curves for any stress within the range studied may be drawn as shown in figure 6. In applying this method, it must be remembered that inflections in the creep curves may be expected at the higher stresses and temperatures (³) and that such inflections make the proposed method invalid. For that reason the curves in figure 6 have been terminated at a plastic strain of one per cent on the assumption that the deformation usually exceeds this value before inflections are found. Further experience with the application of the proposed method may indicate a change in this arbitrarily assumed limit of plastic deformation prior to inflections, but this may be made without affecting the validity of other assumptions.

The relations among the three variables, stress, deformation, and time at constant temperature, as given in figure 6, may be put into more convenient form as shown in figure 7 by the method illustrated in figure 1. The method of presentation indicated in figure 7 is suggested as a convenient form for the comparison of test data and for design use.

Effect of temperature.

For the particular material used in the foregoing discussion, complete data were available at only one temperature. To investigate the effect of the fourth variable, temperature, use was made of valuable test data on a similar alloy very kindly furnished for the purpose by J. J. Kanter, of the Crane Company. The test methods used for obtaining these data (¹⁴) are sowewhat different from those of the author, but the proposed method of analysis is equally applicable as shown in figures 8 to 14, inclusive. Two of these figures require further comment. In figure 11, an attempt was made to establish relations between stress and the constants of the creep equation. While this method has some advantages over the simpler procedure shown in figure 5, the use of logarithms of the constants prevents full utilization of the desirable assumption that the curves pass through the origin. From the applications made up to the present time it appears that the method of figure 5 is preferable to that of figure 11.

Figure 12 shows creep-rate relations at the end of various periods of time. The final velocity for each stress is the same as the v_0 value of figure 10 corresponding to the asymptote of the velocity-time curve. These curves representing a material in wich the creep rate decreases continuously during a test of 1 000 hours gives some indication of the probable effect of length of test upon the minimum creep rate measured. For this material it appears that very little would have been gained by prolonging the test beyond 1 000 hours.

An approximate method of analysis for the reduction of the data for 1 000° F., 1 200° F., and 1 400° F. to charts similar to figures 7 and 14 is shown in figures 15 to 25, inclusive. At these higher temperatures the validity of extrapolation of the creep curves is reduced on account of probable inflections (³). While the accuracy of this extension of the analysis is questionable, it throws some light on a problem which has been rather obscure. Bailey (¹⁵), Tapsel (¹⁶), and others

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(¹⁴) « Long-Time or Flow Tests of Carbon Steels at Various Temperatures With Particular Reference to Stresses Below the Proportional Limit », by J. J. Kanter and L. W. Spring, *Proc. A.S.T.M.*, vol. 28 (1928), part 2, pp. 80-106.

(¹⁵) « The Trend of Progress in Great Britain on the Engineering Use of Metals at Elevated Temperatures », by R. W. Bailey, J. H. S. Dickinson, N. P. Inglis, and J. L. Pearson, Symposium on Effect of Temperature on Metals, *A.S.M.E.-A.S.T.M.*, pp. 227-231, 1932.

(¹⁶) « The Strength at High Temperatures of a Cast and a Forged Steel as Used for Turbine Construction », by H. J. Tapsell and A. E. Johnson, Department of Scientific and Industrial Research (London), *Special Report* No. 17, 1931.

have shown the effect of temperature upon allowable stress for various minimum creep rates. With the exception of the work of Mr. Kanter (14) very little has been published to indicate stress-temperature relations for various amounts of total creep within the life of the material in service. Bailey, *et al.*, in their reply to Mr. Kanter's discussion (15) defend the use of creep rate rather than total creep by stating that it avoids a treatment « too unwieldly for practical purposes ». A comparison of the two methods is shown in figure 26. From these curves, two important conclusions may be drawn. The stress-temperature relation is not fixed by a given creep rate but it is necessary also to allow for the creep at a more rapid rate in the early stage of the test. Furthermore, the rapid decrease in allowable stress indicated by the constant creep-rate curves may be replaced by decidedly flatter curves based on total creep. For the case in which the allowable stress at one temperature is known and it is desired to estimate a working stress for a higher temperature, this type of curve is suggested.

Figure 27 represents the type of chart which may be constructed from charts similar to figures 14, 23, 24, and 25 for any desired combination of service life and allowable deformation. In this way it is possible to show graphically the desired relations among the four variables, temperature, stress, deformation, and time in a form convenient for design use.

Similar analyses have been applied to other materials from various sources with promising results. Application to tests of two non-ferrous alloys at two slightly elevated temperatures showed practically straight-line creep curves in tests of two months' duration. In this case the entire analysis required only the plotting of curves similar to figures 3, 5, and 7 for each material at each temperature. This indicates that further investigation of the subject of analysis of creep data may lead to simpler methods than those suggested here.

In conclusion, the assumption has been introduced that the long-time tension or creep curve approaches a straight line in a comparatively short time and that it may be replaced by a straight line for the purpose of extrapolation. Relations are established between creep properties and stress which indicate a possibility of avoiding very long creep tests at low stresses for the assignment of safe working stresses. A systematic method of interpretation of creep data is suggested as a means of correlating existing data from various sources and the reduction of such data to a form that will be convenient for comparison.

Acknowledgments.

The author wishes to acknowledge his indebtedness to Dr. A. NADAI for his unfailing interest, encouragement, and helpful criticism and suggestions; to Messrs. C. E. CRANG and K. R. WAUGH for their conduct of creep tests and to Mr. R. E. PETERSON and the Westinghouse Electric and Manufacturing Company for permission to publish the results.

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Welding in the construction of goods wagons, passenger coaches, locomotives and railcars,

by Dipl.-Ing. OTTO BONDY, V.D.I., M.I.A.B Struct. E.

(From *The Railway Engineer.*)

It is only within the past few years that welding has been used at all extensively in the construction of railway vehicles. The apparently backward policy of railways in this respect was, however, attributable to the primary importance rightly attached to considerations of safety. From the commercial standpoint safety was, and still is, essential in itself and in its bearing on the effective competition of railways with other means of transport. Also, from the technical standpoint, it did not follow that welding, which had been applied successfully to a variety of vessels, pipes and structures mainly under static load, could be used with equal success and security in railway vehicles subject to severe dynamic stresses. The doubts formerly entertained on this point have, however, been removed not only by scientific research but also by practical experience under difficult conditions of operation. Welded connections have, in fact, withstood dynamic stresses in service much more successfully than either riveted or bolted connections.

Sooner or later, a riveted or bolted connection becomes loose and begins to « knock » with the result that the holes become progessively larger, and rusting accelerates the deterioration. On the other hand, in collisions between welded test wagons it has always been found that the frame or body has been bent, the welded connections remaining uninjured. In other words, the elastic limit of the structural material is exceeded without any change being evident in the welds. This is not a matter of chance but is an occurrence with which every welding expert is thoroughly familiar. The elastic limit of the deposited metal is higher than that of the material of the parts joined, hence the latter are deformed first, provided that the parts are correctly designed and arranged.

Importance of design.

The conditions to be fulfilled are not as simple as they might appear to be. In order to produce a design suitable for welding, a vast amount of special knowledge is required not only in the field of vehicle construction but also in welding technology. A practical knowledge of welding is indispensable to the designer, and special experience is required for the correct choice of welding process, arrangement of component parts, distribution and sequence of welding operations. In addition to this practical experience, the checking of designs by computation is equally necessary and, in many countries, there are already official rules relating to calculations on welded joints.

Special regulations recently issued in Germany concerning the construction of welded vehicles are based generally on the German rules for welded steel structures, and they provide the designer with numerical data for design and construction. The DIN 4100 rules issued in 1932 were modified and amplified in July, 1933, by important clauses relating to the examination of welders and the permissible stresses in welded joints. These stresses form the basis of design and, as shown by the accompanying table, their values are considerably increased under the new rules. The stress permissible in the weld is obtained by multiplying the permissible stress in the structural material by a reduction factor *k*, values of which are given in the table. Taking, for example, a mild steel with a permissible working stress of 1 200 kgr. per sq. cm. (17 064 lb. per sq. inch), a butt-welded joint in this material may be stressed :

In tension to 0.75 × 1 200 = 900 kgr. per cm² (12 800 lb. per sq. in.) ; and in compression to 0.85 × 1 200 = 1 020 kgr. per cm² (14 500 lb. per sq. inch). The permissible bending and shear stresses, and the stresses in filet-welds, can be calculated in the same way, using the appropriate values of *k*.

Increase in permissible stresses in welded joints under German rules.

Kind of joint.	Kind of stress.	Factor *k*		Increase in *k*, per cent.
		Old.	New	
Butt welds	Tension . . .	0.60	0.75	25.0
	Compression. .	0.75	0.85	13.3
	Bending . . .	Like tension and compression.		
	Shear	0.50	0.65	30.0
Fillet welds	Any	0.50	0.65	30.0

I. — Goods wagons.

Successful attempts to build welded goods wagons were made in Germany as early as 1927. The first constructions included large tank wagons of 45 m³ (9 900 gallons) capacity, the tanks of which were oxy-acetylene butt-welded (1). Later, a large number of refuse wagons of 100 m³ (3 535 cu. feet) capacity were built by arc-welding, a saving of 10 % in the weight of steel being effected, compared with riveted construction. Welding has also been used successfully in the construction of pulverised-coal wagons and self-emptying wagons, the smooth inner surface greatly facilitating complete emptying. Water drains more easily from the welded vehicle, both inside and out, the paint lasts longer, and the life of the vehicle is considerably prolonged. The water-tight sealing of the interstices between parts is a further advantage of welding. The rounding of angles by fillet welds facilitates painting and improves the appearance. On external surfaces, exposed to rain, fillet welds should be continuous even though they need not be so for strength; on protected parts, however, discontinuous welds suffice provided that they give the requisite strength.

An interesting example of a welded wagon frame built by the London & North Eastern Railway was recently described (2) reference being made also to experience in New Zealand, the U.S.A., Egypt and Belgium. The accompanying illustrations show a new goods wagon built for the German State Railways by the Waggonfabrik Uerdingen (Rhein), the whole of the body as well as the underframe being electrically welded, and rivets and screws being used only for parts which must be detachable or renewable. The clean finish of the vehicle is evident from figure 1, and the combined lightness and strength is shown

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(1) See Bondy, *Glasers Annalen*, August 14, 1928.

(2) See *The Railway Gazette*, September 1, 1933, page 321, and also *The Railway Engineer*, December, 1933, page 376.
See also *Bulletin of the Railway Congress*, August 1933, p. 784, and October 1933, p. 953.

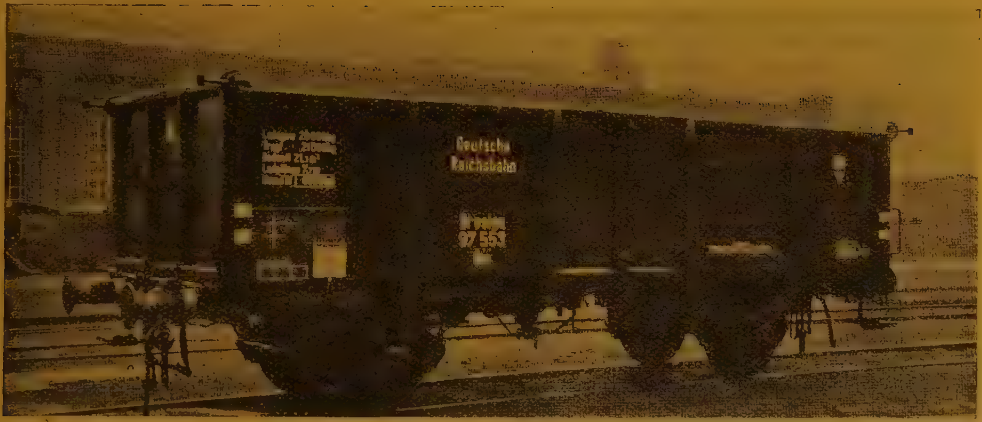

Fig. 1. — Electrically-welded 20-ton goods wagon built by the Waggonfabrik Uerdingen A.-G. for the German State Railways.

by the fact that the wagon weighs only 8 980 kgr. (8 tons 16 cwt. 3 qr.), including wheel sets, couplings, buffers and automatic brakes, the carrying capacity being 20 metric t. (19 tons 14 cwt.). The maximum length is 7.7 metres (25 ft. 3 1/8 in.) and the loading surface inside the body is 21.3 m² (229 sq. feet).

Figure 2, with one end and the central portion of the floor removed, shows the inside of the body and reveals the longitudinal and cross bars of the welded underframe. Openings are provided in the cross bars, along the axis of the wagon, for the passage of the brake rods. The remarkably simple welded details of

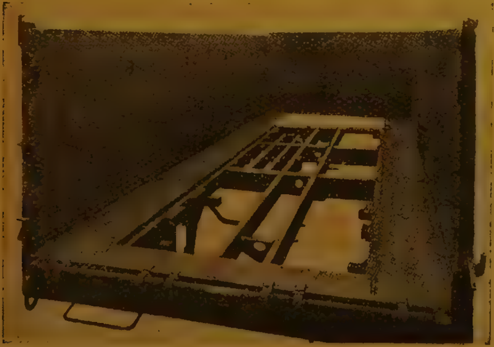

Fig. 2. — Interior of welded wagon, showing welded underframe.

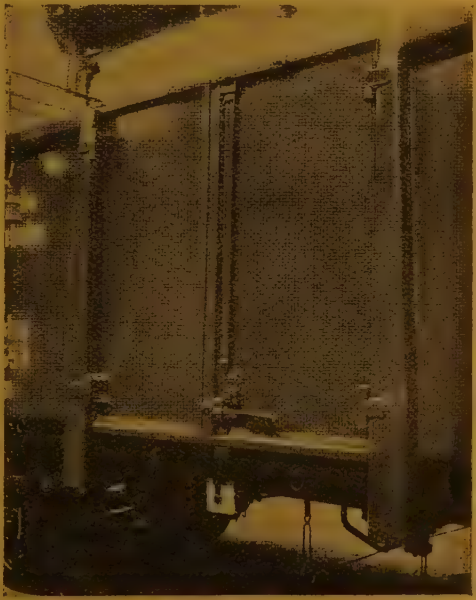

Fig. 3. — Double side door with posts, frames and attachments welded together.

the side doors are shown in figure 3, the uprights of the body acting also as door posts. These uprights are of pressed plate construction, widening towards the bottom in order to allow for the increasing bending moment, the attachment to the sides being made by continuous welds. Finally, figure 4 shows the connection between the ends and sides, the advantages of the welded construction in lightness and appearance, compared with cast and riveted parts, being again apparent.

Fig. 4. — Connection of end to sides of welded goods wagons.

The favourable experience with welded goods wagons in Germany during recent years will, no doubt, lead to their more extensive use. Apart from their lower first cost, and technical superiority, the saving in deadweight results in a reduction in operating costs which continues throughout the life of the vehicles.

II. — Passenger coaches.

The reduction of dead weight is one of the most pressing problems in all forms of railway traction and for all classes of rolling stock, and there can be little doubt that welding will be used to an ever-increasing extent instead of riveted connections and steel castings in the construction of passenger coaches.

The technical capabilities and advantages of welding are well known, but it is not always realised to what an extent the weight of coaching stock can be reduced by this means. The ratio of dead weight to useful load is an economic factor of primary importance, particularly in relation to the competition between rail and road transport. Instead, however, of a systematic reduction in the dead weight of rolling stock, heavier constructions have been introduced during recent years until, to-day, the dead weight per seat is about 400 kgr. (882 lb.) in the ordinary third-class coach, over 600 kgr. (1 323 lb.) in eight-wheeled corridor express coaches, about 1 000 kgr. (2 205 lb.) in first- and second-class corridor express coaches, and as much as 2 500 kgr. (5 512 lb.) in the case of twelve-wheeled sleeping cars (2).

On the other hand, the dead weight of a motor bus amounts only to about 200 kgr. (441 lb.) per seat, including in this figure the weight of the motor itself. In the case of an express train comprising locomotive, sleeping cars and corridor coaches with a total of 762 seats, the dead weight per passenger is about 1 066 kgr. (2 350 lb.), compared with only 222 kgr. (490 lb.) or about one-fifth as much in the case of a motor bus carrying 45 passengers. Such figures reveal a handicap which railways must overcome by the use of lighter constructions if they are not to lose yet further ground to road transport.

Fortunately, it is possible to effect large reductions in the weight of railway vehicles and locomotives without adopting costly methods or materials of construction.

Practicability of weight reduction.

A few years ago, the term « light construction » was commonly associated with special alloys, particularly alumi-

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(3) See A. Ganspöck, *Verkehrswirtschaftliche Rundschau, Vienna,* September, 1933.

nium alloys as used with great success in the construction of aircraft, but it has since become associated more and more closely with welded construction, especially in the railway field.

A misconception which has considerably retarded the development of lighter rolling stock, and one which is still not entirely removed, is that high speeds can be controlled only where heavy locomotives and heavy vehicles are employed. Actually, provided that the permanent way and wheel sets are in proper conditions, light trains permit maximum rapidity and safety of braking at high speeds and on curves. Naturally, a limit is imposed upon the lightening of locomotives by considerations of the requisite adhesive weight, but this limit is lower where light vehicles are used because a smaller tractive effort then suffices for acceleration and gradient.

Welded bogies.

The accompanying illustrations show various examples of welding in passenger coaches. Thus figure 5 shows a welded main line express corridor coach for the German State Railway Company, the tare weight of which is only 36 tons, as compared with 49 tons for a similar

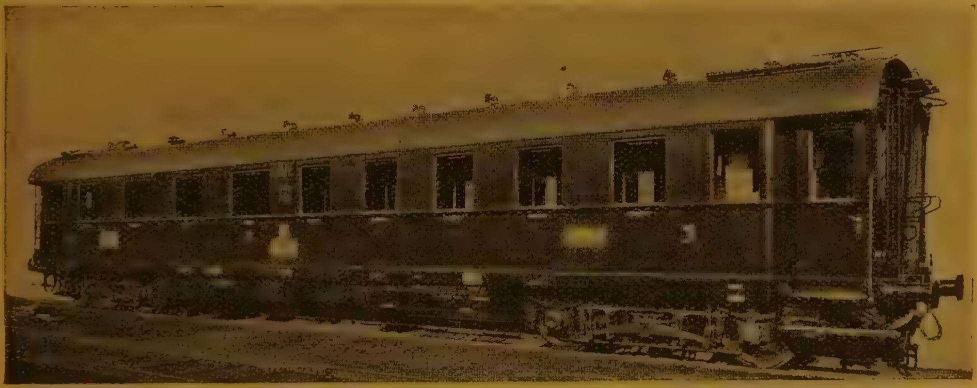

Fig. 5. Electrically-welded main line express corridor coach, built by the Waggonfabrik Uerdingen A.-G. for the German State Railways.

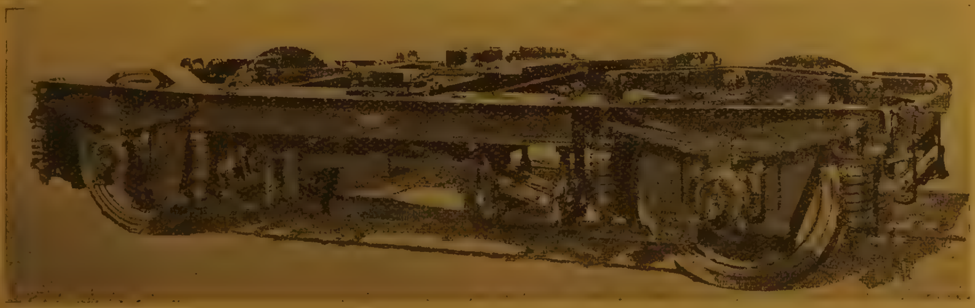

Fig. 6. — Welded bogie as used by the German State Railways for heavy express coaches. Built by Wumag, Görlitz.

vehicle of riveted construction. In figure 6 is shown a welded bogie for such vehicles as well as for mail vans, sleeping cars and restaurant cars. This bogie weighs 6 900 kgr. (6 tons 15 cwt. 3 qr.) in running order, and has a carrying capacity of 24 metric t. (23 tons 12 cwt. 2 qr.). A lighter welded bogie for fast stopping (*Eilzug*) and light express coaches is shown in figure 7. This bogie weighs 5 150 kgr. (5 tons 1 cwt. 1 qr.) in running order, and has a carrying capacity of 18 metric t. (17 tons 14 cwt. 1 qr.). It will be noted that the ratio of dead weight to useful load is almost exactly the same in both cases, viz., 6.9/24.0 = 0.288 for the heavier, and 5.15/18.0 = 0.286 for the lighter bogie. In both instances the bogies consist almost entirely of arc-welded rolled sections and flats. Bolts cannot be completely eliminated, but their use is restricted to such parts as the movable connections of springs and brake rods, and the securing of detachable parts.

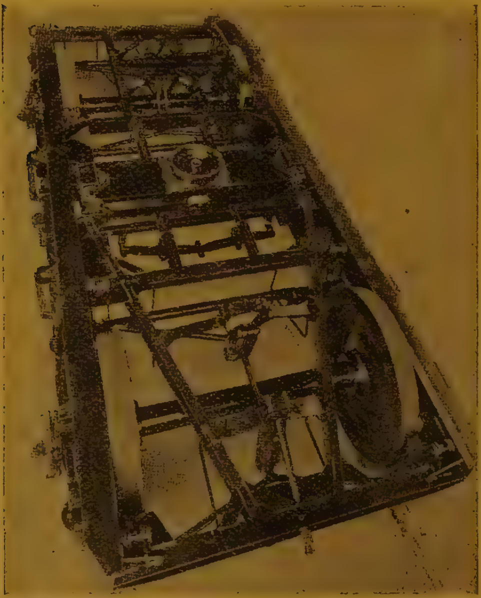

Fig. 7. — Welded bogie for light express coaches of the German State Railways. Built by Wumag, Görlitz.

Not only are there now fully welded express coaches in regular service, but further improvements are continually being introduced by new constructions. In going over from riveting to welding the designer finds it difficult at first to accustom himself to the radically new and simple forms of welding. For example, a number of small angle pieces and supports were formerly used to connect channel frames to cross stays of the same form, whereas such sections are now generally butted together and welded round, as shown in figure 8. In this drawing, the effective lengths of the welds are l^1, l^2, excluding the end craters k; and the thickness of the weld is a, the bending moment being represented by m.

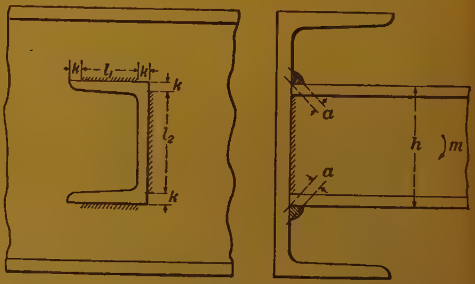

Fig. 8. — Butt-welded connection of frame and cross stay channels.

So-called safety straps were popular in the early days of welding, but are now preferably omitted, as they certainly do not improve the security of the connection. The secret of success lies in first-class execution of welds, and it is necessary not only to train welders thoroughly (4) but also to supervise their work continually and subject a proportion of the finished welds to appropriate tests.

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(4) By courses of at least three months at welding schools in the larger industrial towns.

Testing and stress allowances.

Practical experience in the large German rolling stock works during recent years has solved many problems encountered, and definite rules have been formulated for the construction of equipment, the determination of the sequence of welds, the application of initial stress, and the inspection and testing of welded vehicles. Testing by X-rays has been developed to such an extent that it enables the internal conditions of welds to be determined with considerable certainty. This method is applied to the vehicles of the German State Railways before they are put into service, and it can now be said that a welded vehicle which passes its X-ray tests is at least as safe as any riveted or bolted construction (fig. 9).

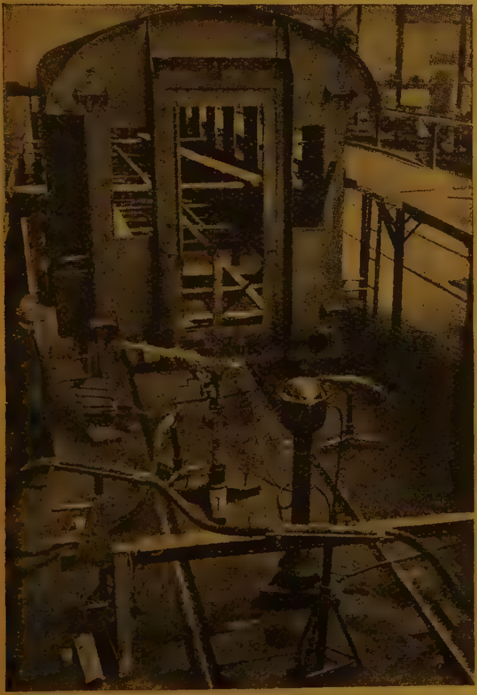

Fig. 9. — Testing by X-ray of welded seams of main-line express corridor coach in the works of the Waggonfabrik Uerdingen A.-G.

Welding rules.

A special book of rules has been issued relating to welded vehicles of the German State Railway Company, giving all the requisite details in ten sections. The permissible stresses differ, in some cases, from those allowed in general structural work and bridge building. In particular, butt welds may be stressed in tension to 80 %, and in compression to 85 %, of the stress allowed in the stock material, compared with considerably lower values in the German standard rules DIN 4100 issued three years ago. Substantial progress has thus been made towards realisation of the possibility that butt welds may, at no distant date, be stressed to the same extent as the material joined.

Great importance is now attached to the toughness of welded connections in vehicles and in locomotive boiler construction. This matter is covered by the above-mentioned rules which impose a notch impact test on a test piece of the form and dimensions shown in figure 10; the bracketed dimensions relate to the use of the earlier pendulum-type apparatus for impact testing. Minimum impact values for standard materials,

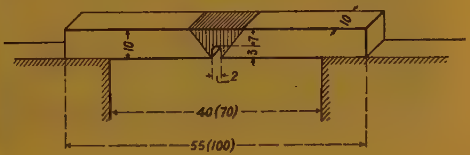

Fig. 10. — Test bar for notch impact test, for the determination of the toughness of welded connections in accordance with the German State Railways rules for welded vehicles. (Dimensions are in millimetres).

annealed and unannealed, are specified as follows :

Material (German standard).		Minimum impact value.	
		Kgr.-M. per cm².	*Ft.-lb per sq. inch.*
St 34	unannealed . .	8	*373*
	annealed. . .	10	*466*
St 37 St 52	unannealed . .	5	*233*

During the last year, the German State Railway Company has placed high-speed railcars in service, including the Flying Hamburger, the undercarriage and body of which are largely of welded construction. Examples taken from high-speed railcars driven by 175-H.P. Diesel motors are given in the accompanying illustrations. Thus, figure 12 shows a bolster beam for an eight-wheeled railcar, in which the free use of gas-cutting by acetylene and oxygen, and butt-welding by electric arc, has resulted in a clean and strong construction. An interesting welded construction for the end-piece or cowl of the roof of the same vehicle is shown in figure 13; the component plates were hammered to shape and then joined by butt welding. Weight is saved by circular openings in the cross stays, and by taking the side and roof plates into consideration in the strength calculations.

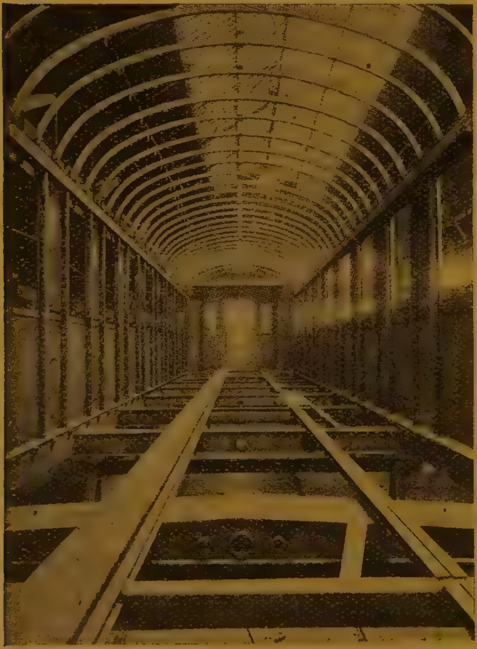

Fig. 11. — Welded frame of the coach shown in figure 5.

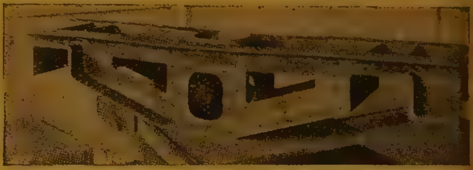

Fig. 12. — Bolster beam of an eight-wheeled Diesel rail motor coach. Built by the Waggonfabrik Wismar, using arc butt-welding and gas cutting by oxygen torch.

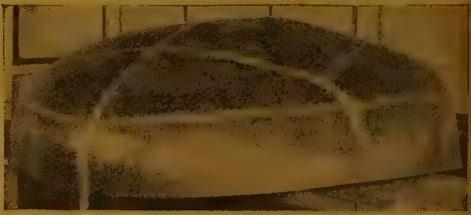

Fig. 13. — Roof-end cover for a Diesel rail motor coach. Built by the Waggonfabrik Wismar by butt-welding hammered plates.

These vehicles are of frame construction consisting of a number of closed frames joined one behind the other. Although the original riveted construction was light, a further 15 % was saved by welding. Resistance welding, as well as arc welding, was applied, the doors, for example, being built by aid of double spot welding machines. The cover plates were relieved of stress before welding by running them twice between rollers. The completed coaches have given entire satisfaction at a speed of 150 km. (93.2 miles) an hour on open track, affording an excellent proof of the capabilities of welding in the construction of passenger coaches.

In conclusion, reference may be made to the welded body of a passenger coach, of the type illustrated in figure 5 shown in figure 11. The principle of self-supporting frame construction has been extensively applied in express coaches of the German State Railways and the weight of cross stays has been greatly reduced by welding (5). Tubular members have proved very successful in the frames and bogies of tramcars, and they were applied also in the Kruckenberg high-speed railcar. As the ideal section to resist buckling, tubes appear to have a great future in the construction of railway vehicles by welding. New sections, new designs and new processes each and all further the aim of reducing dead weight to a minimum.

III. — **Locomotives and railcars.**

Once the feeling was overcome that welded connections were unsuitable for resisting dynamic stresses, welding was gradually applied to all parts of railway rolling stock, progress being more rapid as experience was accumulated. It is now proposed to deal with the uses of welding in the building of locomotives and railcars. In this field the requirements are specially exacting and the slightest defect may have serious consequences. Nevertheless welded connections have proved satisfactory in service over a period of years.

Electric locomotives with welded frames and bogies were built in Germany in 1930 (6) and soon afterwards certain experimental Bo-Bo type locomotives were built by the welding process, the firms concerned being the Berliner Maschinenbau A.G. and the Siemens-Schuckert Werke, Berlin. The construction of welded locomotives has since become increasingly frequent, based on practical experience with the experimental machines and the general advance in welding practice. Meanwhile the development of welding for the construction of buildings and bridges in Germany proceeded apace during the same period, the first *Regulations for Welded Steel Structures* being published in 1930, followed in 1931 by the *German standard rules DIN 4100*. The keenest interest was displayed in the welding of vehicles of all kinds and, although there were no special rules for this class of welding until the appearance of those published by the German State Railways in 1933, an ever increasing number of vehicles and even locomotives were built by welding.

The present state of development is best shown by the fact that, at the end of 1933, no fewer than 28 welded double electric railcars had been ordered by the German State Railway Company. These are to be gradually placed in service as the standard type for internal fast main line services (as opposed to suburban and international services) on electrified lines. Each of these double railcars is 43.625 m. (143 ft. 1 1/2 in.) in length, with four motors aggregating 900 kw. (1-hour rating), the weight in working order being about 92 t. (90 tons 11 cwt.) and they have a maximum speed of 120 km. (74.6 miles) per hour, and three of them 160 km. (99.4 miles) per hour (7). The observation railcars of which two are under construction for mountain service, are specially interesting. They are 19.64 m. (64 ft. 5 1/4 in.) in length and are carried by two bogies 12.70 metres (41 ft. 8 in.) between centres; owing to the welded construction, the weight in working order is only 23 t. (22 tons 12 cwt. 3 qr.).

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(5) See Bondy, *Verkehrstechnik*, Berlin, May 20th, 1933.

(6) *VDI-Zeitschrift*, No. 23, 1930.

(7) *Elektrische Bahnen*, Berlin, January, 1934.

Quite a number of different types of locomotive have already been built by welding. The following particulars relate to the Bo-Bo electric locomotives, series E44, of the German State Railways. The general arrangement comprises two four-wheeled bogies under a so-called « bridge-girder ». The length over buffers is 15.20 m. (49 ft. 10 1/2 in.); the distance between bogie centres is 6.30 metres (20 ft. 8 in.); and the bridge girder is 13.20 m. (43 ft. 3 3/4 in.) in length. A series of 20 such locomotives was built, the mechanical parts by Henschel & Sohn, Kassel, and the electrical equipment by the Siemens-Schuckert-Werke. Compared with earlier locomotives of equal power, welding effected about 30 % saving in weight thus making possible the new wheel arrangement Bo-Bo instead of 1B-B1; in other words, the welded locomotives have simply four driving axles, the use of supplementary carrying axles being no longer necessary (8).

Figure 14 shows the welded bogie frame, which takes the load of the bridge girder and runs on two driving axles. The side plates are 20 mm. (25/32 inch) in thickness, and longitudinal and transverse stiffening plates are fitted as shown. These frames are unsymmetrical, a specially strong cross stay being fitted at one end to take the draw hook. Special buffer beams are used to ensure that impacts are considerably damped before reaching the frames, thus avoiding deformation or other damage. The bogie frames are connected to the bridge girder by centre pins with spherical seatings, and the girder itself is specially designed to suit welding. The outer main side plates are 15 mm. (19/32 inch) in thickness, and the inside longitudinal and transverse members are of thinner plate welded together and in some instances flanged by pressing. The strongest parts of the bridge girder are

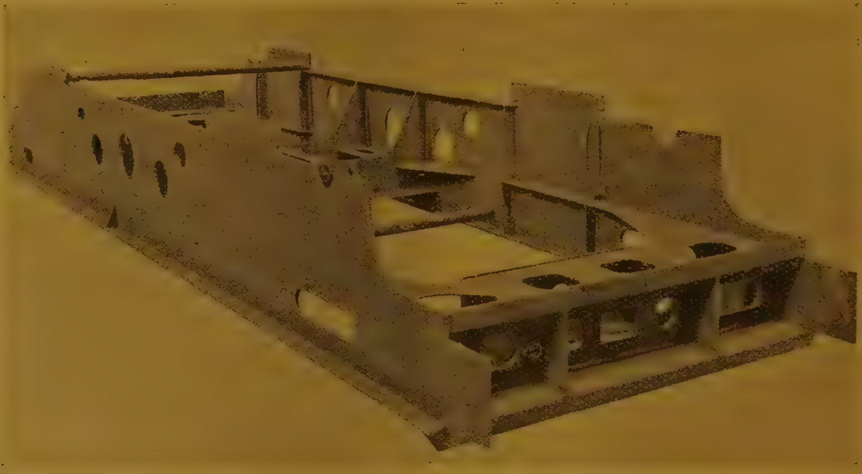

Fig. 14. — Welded bogie frame (without horn blocks, etc.), built by Henschel & Sohn A.-G., Kassel, for electric locomotives (German State Railways).

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(8) *Henschel-Hefte*, November, 1933.

the box-type cross stays carrying the bogie centre pins and springs.

Strength of fillet welds.

Many new problems have been introduced by the welding operations themselves. In general, the requirements of the DIN 4100 rules for welded steel structures have been observed, but the conditions for the examination of welders have been made more severe in a number of instances. The well-known cross joint test, in which three plates are welded together at right angles for the determination of the strength of fillet welds, gave ultimate strengths of 33 to 35 kgr. per mm^2 (20.9 to 22.2 Engl. tons per sq. inch), whereas the DIN 4100 rules require only 26 kgr. per mm^2 (16.5 Engl. tons per sq. inch). The new German State Railway rules also prescribe the same value, 26 kgr. per mm^2 (16.5 Engl. tons per sq. inch) for steel St 37, while that for the high-quality structural steel St 52 is 50 % higher. In this connection it may be noted that the minimum cross-test strength demanded by the rules has also been considerably increased in tests for other welded locomotives for the German State Railways. It has been increased to 30 kgr. per mm^2 (19 Engl. tons per sq. inch) in other extensive welded operations, and this figure has almost invariably been reached in the testing of welders.

Frames and cross stays.

The welded frames shown in figure 15 were built for the cooling tender of a condensing locomotive for Russia. The weight of the tender in working order is about 72 metric t. (70 tons 17 cwt.). The frames consist of two standard I girders about 12 m. (39 ft. 4 1/2 in.) in length, and the cross stays are of welded construction, extra resistance to bending

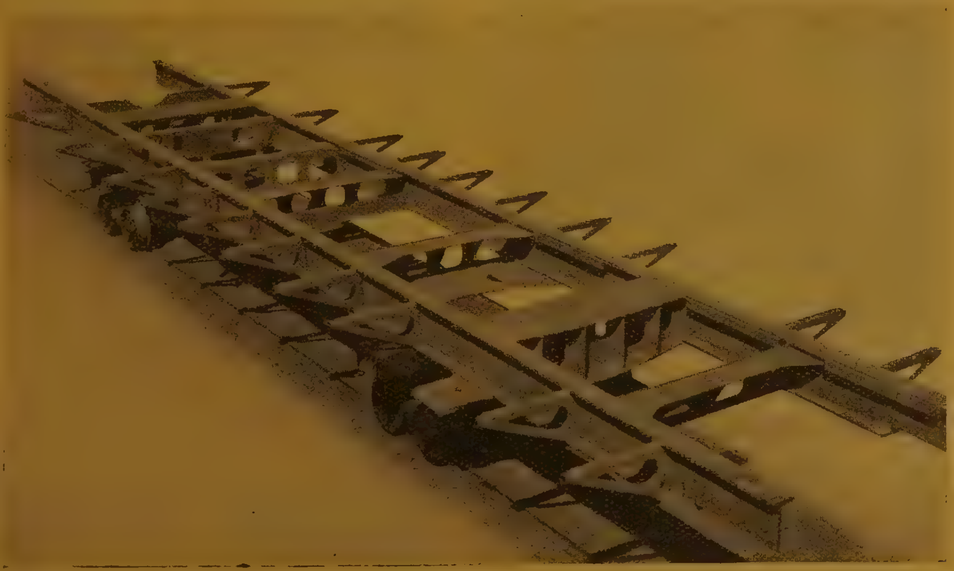

Fig. 15. — Electrically welded frame for the cooling tender of a condensing locomotive.

being obtained by widening the top plates. A series of pressed bracket plates is welded to the outside of the frames as shown. The great advantage of such welded constructions lies in the fact that the connections are not weakened by rivet holes; also, the cleanest possible connections are effected by direct welding with rounded fillets. Small parts such as connecting angles, straps and cover plates are avoided, and the supervision and maintenance of the construction are correspondingly facilitated.

A particularly interesting example of welding is illustrated in figure 16, which shows a welded frame cross stay for *Pacific* express locomotives of Series 03 of the German State Railways. As formerly cast in steel, these stays weighed about 1 500 kgr. (3 307 lb.) each, but the welded construction weighs only 1 200 kgr. (2 646 lb.), a saving of 20 %. Following this successful result, the German State Railway Company has adopted the same type of welded cross stay in a number of new locomotives.

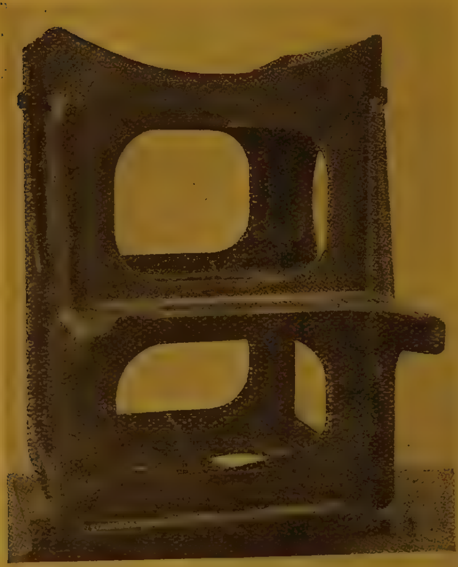

Fig. 16. — Welded construction in place of cast steel for the frame cross stay of a locomotive built by Henschel & Sohn A.-G., Kassel, for the German State Railways.

Shrinkage stresses.

Shrinkage stresses set up by welding can now be almost completely controlled in electrically welded structures of the types considered. This is not a matter of calculation but rather one of practical experience. The specification for the bridge type girders, about 14 m. (45 ft. 11 1/4 in.) in length, for electric locomotives, does not permit of an upward deflection in excess of 4 mm. (5/32 inch), but prohibits any downward bending. In order to comply with these requirements, the shrinkage effect of welding is compensated by initial bending of the parts to be joined, the direction and amount of such bending being determined by trial. Thus, after it had been found that the first welded frames sagged to the extent of 3 mm. (nearly 1/8 inch.), which is not permissible, later constructions were finished with an upward deflection generally not exceeding 2 or 3 mm. (5/64 to 1/8 inch) (9).

Thorough examination of the welded frames of an electric locomotive after several years in service, running 100 000 km. (62 140 miles) total, revealed no crack or fracture in the welds, hence no repairs were required; in riveted frames, on the other hand, it is almost invariably necessary to replace loose rivets after some time in service. The confidence now placed in welding is demonstrated by many features of modern German practice. For example, cast steel parts are extensively replaced by welded plate constructions in the 1C-C1 locomotive of the AEG. Also, the casings of the nose-suspended motors of the Bo-Bo locomotive are welded, and so are the naves of the gears. Even the connection between gear wheels and hollow shafts is effected by electric welding, both parts being of cast steel; in this case, heavily covered electrodes are used and the weld is made on a thickened part of the shaft in order not to weaken the fully stressed section of the shaft by welding. Such constructional measures must be carried down to the smallest detail in order that welding may actually result in a technically superior product, and the main responsibility for this lies with the designer whose experience must therefore include a practical knowledge of welding technology.

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(9) *Elektrische Bahnen*, Berlin, October, 1933.

Testing of welds.

The testing of welded constructions is particularly important in the locomotive field and, in addition to the usual mechanical tests partly covered by rules, the German State Railway Company makes free use of X-ray examination. Figure 17 shows an X-ray equipment for pressures up to 250 000 volts, mounted on a truck with pneumatic tyres and so arranged as to protect the operator against injury from either electric shock or X-ray burns. This is one of many radiographic outfits used in workshops and it is not uncommon, when examining welds by this method, to find that although the welding is satisfactory there are defects in parts outside the joint. For radiographic investigations of locomotive boilers, the X-ray tube itself is taken from the truck and applied to the welded joint under examination.

A specimen of an X-ray photograph is reproduced in figure 18. In this case, an internal crack about 350 mm. (13 3/4 inches) in length was revealed in the downcomer tube plate of a steam drum. Defects of this type can be discovered by no other means, short of destructive testing, and a radiographic supervision of vital parts of the locomotive and boiler — including but not restricted to the welded connections — ensures the highest degree of safety that can at present be attained.

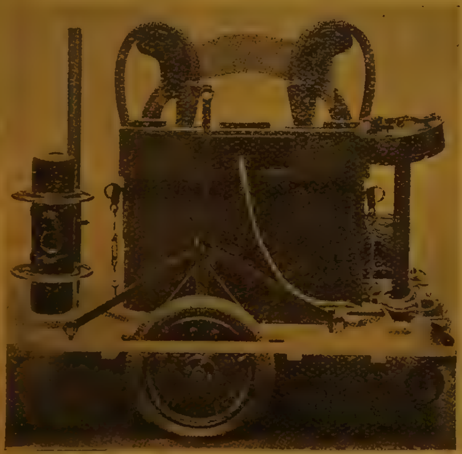

Fig. 17. — Portable X-ray testing apparatus for pressures up to 250 000 volts, constructed by Richard Seifert & Co., Hamburg.

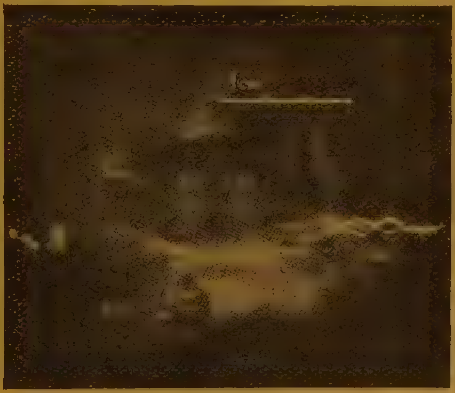

Fig. 18. — Radiograph of internal cracks in downcomer tube plate.

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920-H.P. Diesel-electric locomotive for the Paris-Lyons and Mediterranean Company's Algerian Lines.

(Le Génie Civil.)

The use of the Diesel engine for railway traction, the first application dating back more than 20 years, has increased considerably recently, thanks to the progress made in the construction of this type of engine. One of the advantages of the explosion motor over the steam engine is the insignificant quantity of water it uses, this quantity being limited to the loss of engine cooling water. In countries where water is scarce or of bad quality, this advantage is an overriding one, so much so that the use of Diesel locomotives would appear to be essential in, for example, the case of a Trans-Sahara railway.

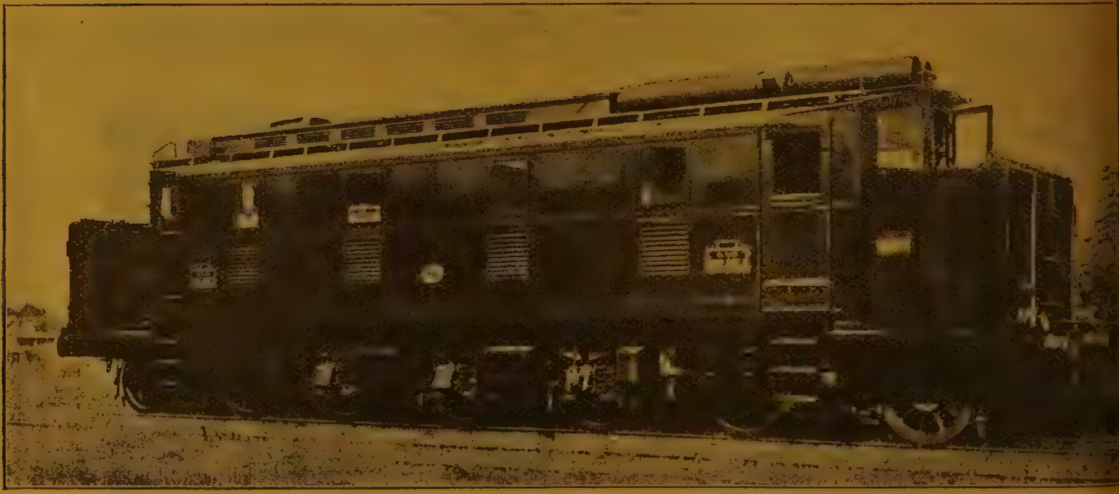
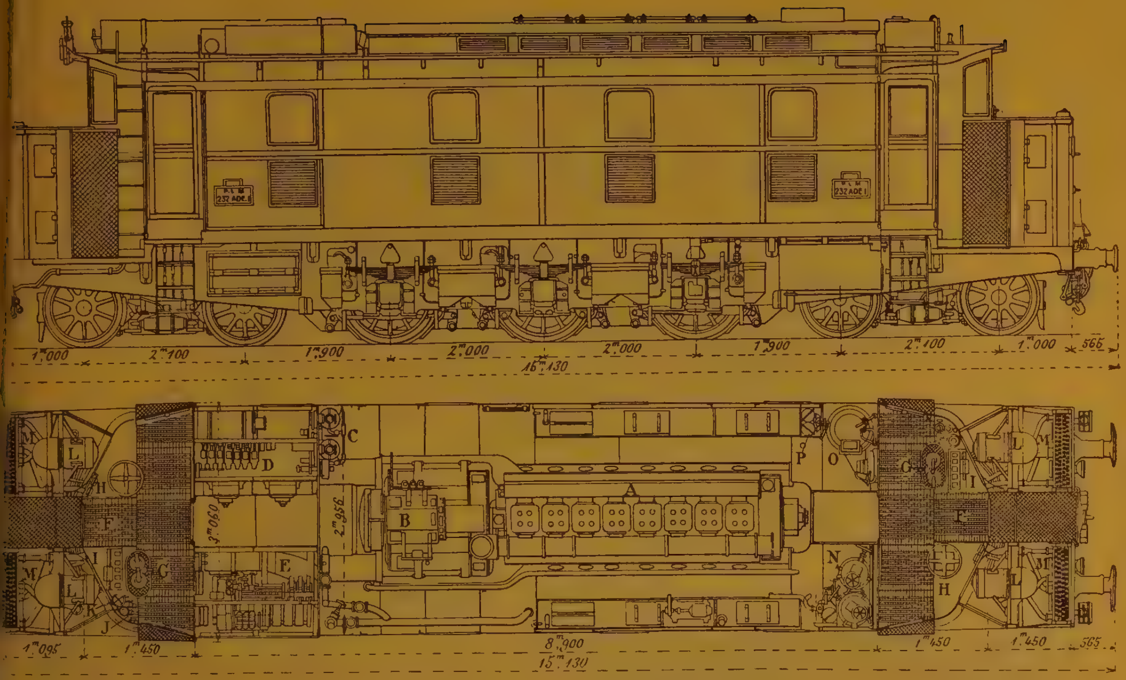


Fig. 1. — The new Diesel-electric locomotive for the Paris-Lyons & Mediterranean Company's Algerian lines.

At the present time steam locomotive operation is difficult in Algeria, owing to the bad quality of the water; to meet this difficulty, the Algerian System of the Paris-Lyons & Mediterranean Company decided to use Diesel-electric traction. Treated water can be used for cooling the engines without any serious increase in cost. The proposal was to work light high-speed trains over the Algiers-Oran line.

The engine was to be designed to run over 1 000 km. (620 miles) without taking fuel, etc., whilst being able to work in the special atmospheric conditions : outside temperature as high as 50° C. (122° F.), sandy wastes to cross, etc.

On these bases, the *Société Générale de Constructions Electriques et Mécaniques Als-Thom* built in its Tarbes shops (formerly *Constructions Electriques de France Company*) a 2 C 2 (4-6-4) locomotive with a M.A.N. Diesel motor of 920 H.P. for a maximum speed of 115 km. (71.5 miles) an hour.



Figs. 2 and 3. — Elevation and horizontal sectional plan of the Diesel-electric locomotive.

A, Diesel engine; B, generators and exciter; C, de-oiler of brake compressors; D, E, control gear compartments; F, driving compartment; G, controller; H, hand brake wheel; I, control and measuring instruments; J, automatic brake valve; K, moderable brake valve; L, motor-driven fan for radiators; M, radiators; N, compressed air bottles for starting engine; O, heating boiler; P, fuel filter.

This engine, the outside appearance and the main features of which are shown in figures 1 to 6, has three pairs of driving wheels with two carrying bogies; its leading characteristics and dimensions are given in the table below.

The mechanical part of this locomotive, the main features of which are shown in figures 2 and 3, consists of a main plate frame, the steel plates being 30 mm. (1 3/16 inches) thick, cross braced by steel stays. The bogies are of the P.L.M. type, the self-centering arrangement being obtained by inclined planes, with helicoidal surfaces, and the driving axles are driven individually by nose-suspended motors through double trains of elastic toothed gears. The body is all-metal and is rigidly fastened to the locomotive frame.

Leading characteristics and dimensions of the locomotive.

Length over buffers	15.130 m. *(49 ft. 7 in.)*
Rigid wheel base	4.000 m. *(13 ft. 1 1/2 in.)*
Total wheel base	12.000 m. *(39 ft. 4 1/2 in.)*
Bogie wheel base	2.100 m. *(6 ft. 10 11/16 in.)*
Diameter of driving wheels	1.250 m. *(4 ft. 1 3/16 in.)*
Diameter of carrying wheels	1.010 m. *(3 ft. 3 3/4 in.)*

Minimum radius of curve	120 m. *(6 chains).*
Total weight, running order	100 000 kgr. *(220 460 lb.)*
Adhesive weight	52 000 kgr. *(114 640 lb.)*
Continuous power of the Diesel motor at 20° C. *(68° F.)* and under 760 mm. (29 7/8 inches) of mercury at the speed of 700 r.p.m.	920 H.P.
Maximum power absorbed by the auxiliaries :	
Radiator fans	28 H.P.
Traction motor fans	15.8 H.P.
Air compressors for the brake	26 H.P.
Total tractive effort at the wheel tread under continuous load	4 800 kgr. *(10 582 lb.)*
Corresponding speed	39.5 km. *(24.5 miles)*
Maximum speed in service	115 km. *(71.5 miles)*
Capacity of tanks :	
Water	1 300 l. *(286 Br. gall.)*
Fuel	2 200 l. *(484 Br. gall.)*
Lubricating oil	720 l. *(158.4 Br. gall.)*

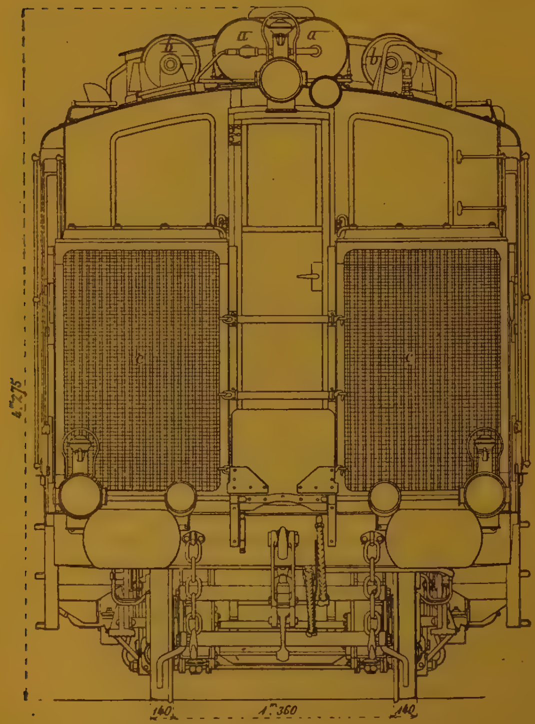


Fig. 4. — End view of the locomotive.

a, main air reservoirs; *b*, silencer; *c*, radiator.

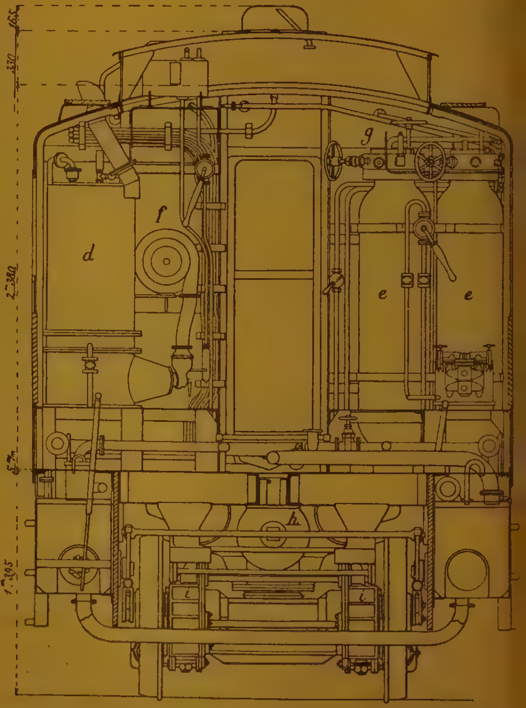


Fig. 5. — Cross section of the locomotive.

d, heating boiler; *e*, starting air bottles; *f*, heating boiler blower; *h*, brake cylinder; *i*, axle box.

All pairs of wheels are braked, the Westinghouse automatic and moderable brake being fitted in addition to the hand brake which latter acts on the driving

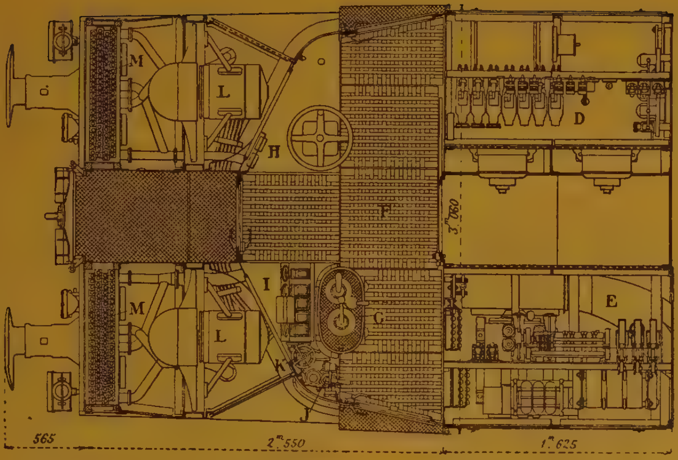


Fig. 6. — Plan of a driver's compartment and control gear section.
(The letters have the same meaning as in figures 2 and 3.)

wheels only. The driving wheels are fitted with Gresham's air sanders in both running directions.

The Diesel engine which drives the locomotive is a M.A.N. engine, the *Société Générale de Constructions Mécaniques* (formerly Messrs. *E. Garnier et Faure-Beaulieu*) (fig. 7) holding the license for France. Its leading dimensions are :

Cycle	4-stroke.
Number of cylinders	8
Method of injection	Mechanical.
Bore.	300 mm. *(11 13/16 inches).*
Stroke	380 mm. *(14 15/16 inches).*
Speed, revolutions per minute	700
Continuous power at speed of 700 r.p.m. . .	920 H.P.
Weight including the pumps	9 t. *(8.86 Engl. tons).*

The main engine block, cast in a single piece, forms the upper half of the crank case and cylinder casing ; the brackets carried by the foundation, the crank shaft and cam shaft bearings are cast integrally with it. The cylinder liners are pressed in from the top. The crank case is completed by the oil pan.

The reactions of the driving forces on the cylinder heads and on the crank shaft bearings are not transmitted by the main casting, but by vertical tie bars in special steel passing through the casting.

The crank shaft is a one-piece forging with a flange at one end forged on it. The connecting rods are drilled and are lubricated under pressure up to the gudgeon pins.

The piston rod is removed by lifting it out after the cylinder head of the corresponding cylinder has been taken off and the large end cap of the rod has been removed.

The injection pumps are of the M.A.N. type, the main feature of which is that as the side faces of the piston play no part in the distribution, the piston can be fitted closely over a longer length and remains tighter longer.

The shape of the combustion chamber, bounded by the cylinder head and the top of the piston at the top dead centre, is simple : the injection takes place through a central pulveriser with diverging jets, closed by a needle valve which lifts automatically. This design was selected as it distributes the fuel correctly through the air and cools as little as possible the gases before and after they do their work.

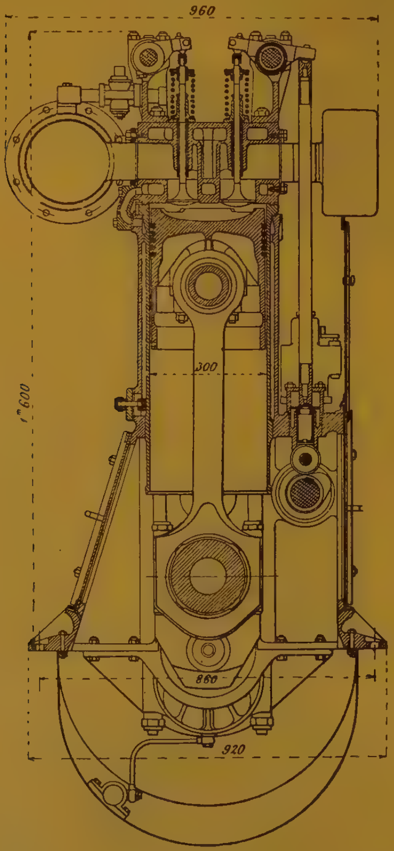


Fig. 7. — Vertical section of the Diesel engine (through the valves).

The consumption recorded during the trials is under normal load 162 grammes (5.71 ounces) of fuel of 10 000 calories (*18 000 B.T.U./lb.*) per H. P. supplied to the generators per hour, that is an overall efficiency of 39 %.

The normal running speed is 700 r. p. m., but by means of the pneumatic control of the engine regulator, this speed can be set at 600 or 400 r. p. m. The speed of 600 r. p. m. is a useful one to resort to when the power required is much below the maximum. The Diesel engine then works nearer its normal load, and at this speed the wear of the engine is reduced.

The speed of 400 r. p. m. is of value when the engine is running light.

The engine drives the following auxiliaries mechanically :

1. A high-pressure compressor producing the air for starting;
2. A gear pump for circulating the lubricating oil under pressure;
3. A reciprocating pump which circulates the cooling water.

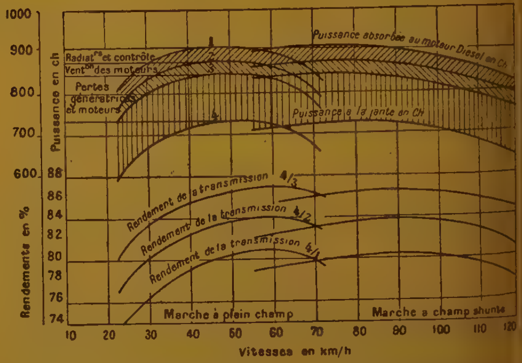


Fig. 8. — Power developed by the Diesel engine and power absorbed by the auxiliaries.

Explanation of French terms :

Rendement en % = Percent efficiency. — Puissance en ch. = Horse power. — Radiateurs et contrôle = Radiators and control. — Ventil^{on} des moteurs = Motor cooling fans. — Pertes génératrices et moteurs = Losses in generators and motors. — Puissance absorbée au moteur Diesel en ch. = Power, in H.P., absorbed by Diesel engine. — Puissance à la jante en ch. = Power, in H.P., at the tread. — Rendement de la transmission = Efficiency of the transmission. — Marche à plein champ = Running with full field. — Marche à champ shunté = Running with shunted field. — Vitesses en km. h. = Speeds in km./h.

The locomotive is fitted with an ample forced-draught radiator plant for cooling the circulating water and lubricating oil. Owing to the high temperatures experienced in North Africa, this plant has been made of large capacity.

The four oil and water radiators are arranged on each side of a circulating gangway at the front and back ends, so as to make use of the wind pressure due to the speed. The motors driving the fans of these radiators are also fitted with a system of regulator which gradually reduces their speed as that of the locomotive increases, so as to pass a practically constant quantity of air through the radiators. This arrangement has made it possible to reduce considerably the power taken by the auxiliaries and to get a satisfactory overall efficiency out of the drive.

The direction of rotation of the fans naturally reverses as the direction of running of the locomotive is changed.

A heating boiler is provided to produce hot water circulated through the engine and the lubricating oil sump in order to facilitate starting the engine in Winter and to make it possible for the engine to stand out-of-doors when the outside temperature is less than 0° C. (32° F.).

The air for starting the engine is contained in two bottles at 60 kgr./cm² (853 lb. per sq. inch) pressure. The capacity of these bottles is such that the engine can be re-started more than 50 times without recharging them.

Sand and dust is prevented from getting into the engine by an air filter on the admission side of the engine.

Electrical equipment. — Figure 9 shows the simple layout of the electrical equipment of this engine. It includes a generator group, three traction motors, fan and compressor groups, a battery, and the electro-pneumatic control gear.

The generator group consists of :

a) A 6-pole main generator giving 870 amperes at 670 volts at the constant working temperature of 110° C. (250° F.) at 700 r.p.m., supplying current to the three traction motors;

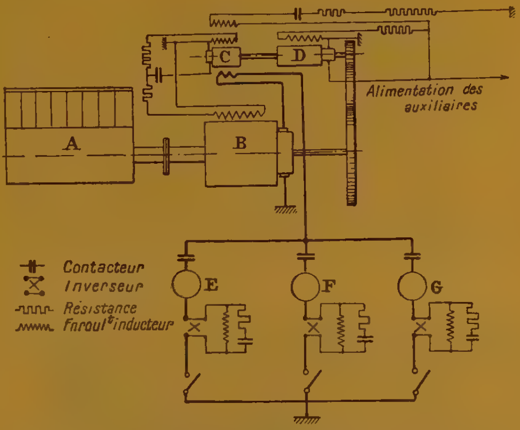


Fig. 9. — Diagram of the electrical equipment of the locomotive.

A, Diesel engine; B, main generator; C, exciter with three windings; D, auxiliary generator; E, F, G, traction motors.

Note: Alimentation des auxiliaires = feed to auxiliaries. — Contacteur = contactor. — Inverseur = switch. — Résistance = resistance. — Enroult inducteur = armature winding.

b) An auxiliary generator giving 550 amperes at 155 volts at the constant working temperature of 110° C., at 2 080 r.p.m., supplying the main field windings of the exciter, the motors of the radiator and traction motor fans, and the brake motor compressors;

c) An exciter of 105 amperes, at 60 volts, at the constant working temperature of 110° C., and 2 080 r.p.m., feeding the field windings of the main generator. It is anti-compounded by the current given by the latter.

The two last machines are arranged above the main generator on a single gear-driven shaft.

The three traction motors, of the nose-suspended type with forced ventilation and roller bearings, have the following characteristics :

Continuous working at 110° C. (250° F.) at 663 r.p.m. . . .	260 A.	750 V.
Continuous tractive effort at the tread	1 600 kgr. *(3 527 lb.)*	
Speed corresponding to the continuous tractive effort	39.5 km. *(24.5 miles)* p.h.	

A motor-driven fan set provides the air for the forced ventilation of the traction motors ; four motor ventilators cool down the traction motors ; two motor compressors supply the air for the brake ; a battery of 64 cells, of 55 ampere-hours capacity, provides current for the lighting and for the control circuits. The electropneumatic control gear is principally noteworthy for the system of automatic regulation invented by Mr. Royer, Chief Engineer for rolling stock of the *Als-Thom* Company. This equipment consists of an exciter with three field windings, shunt, separate, and anti-compound, and an automatic rheostat mechanically controlled by the speed governor of the Diesel motor.

This equipment as a whole makes the main generator torque characteristic very sensitive to the speed, so that the engine can be worked at practically constant speed and output at all useful working conditions of the generator.

This electrical regulation is itself combined with a device for limiting the amount of fuel injected by the pumps so as to prevent, for example, any overload on the engine due possibly to one or several cylinders working irregularly for a time. The traction motors are also shunted automatically so as to widen the speed range of the locomotive, within which the power at the wheel tread remains constant.

As a result of this arrangement, the driver need not pay any attention to the control gear, whether during starting or while running, and can give his whole attention to watching the signals and the track. As the control is automatic, no matter how the controls are handled, there is no danger of overloading any part of the machine.

The curve of figure 10 shows the values of the tractive effort at the tread of the driving wheels in terms of the speeds at maximum excitation. The curve of figure 8 shows the power developed by the Diesel engine, the power absorbed by the auxiliaries and the transmission losses. These curves show that the overall efficiency of the locomotive (excluding the Diesel engine) exceeds 80 % for the most important range of speeds at which the locomotive is used, that is between 45 and 100 km. (28 and 62 miles) an hour, the efficiency of the transmission proper being on the average equal to 85 %.

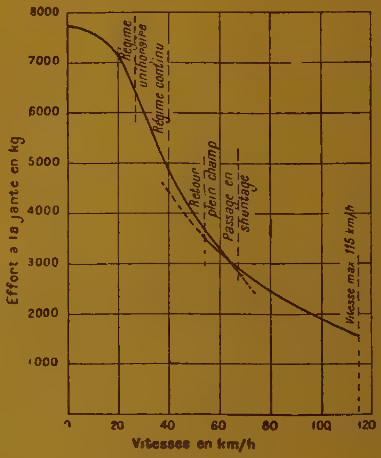


Fig. 10. — Curve of tractive efforts in terms of the speed.

Explanation of French terms :

Effort à la jante en kgr. = tractive effort at the tread, kgr. — Vitesses en km./h. = speed in km./h. — Régime unihoraire = hourly rating. — Régime continu = continuous rating. — Retour plein champ = return full field. — Passage au shuntage = change over to shunted. — Vitesse maximum 115 km./h. = Maximum speed 115 km. (71.5 miles) an hour.

Tests. — On leaving the works, the locomotive was run over 1 000 km. (620 miles) on the Midi Railway, under load and operating conditions laid down by the Algerian lines of the Paris-Lyons & Mediterranean Company.

The following tests were carried out :

Tarbes to Dax and back with a trailing load of 80 tons at 90 km. (56 km.) an hour (the maximum speed on this line)	340 km. *(211.3 miles)*
Tarbes-Bordeaux-Bayonne with a trailing load of 80 tons and a maximum speed of 90 km. (56 miles) an hour	490 km. *(304.5 miles)*.
Bayonne-Bordeaux-Tarbes with a trailing load of 100 tons and maximum speed of 115 km. (71.5 miles an hour	490 km. *(304.5 miles)*.
Total. . .	1 320 km. *(820.3 miles)*.

In addition the engine ran a high-speed endurance test on the Paris-Lyons & Mediterranean from Paris to Marseilles. For this trial, the train was limited to 80 tons, i. e. two bogie carriages. The total distance of 863 km. (536.3 miles) was covered in less than 9 hours (stops not included) that is at an average speed of approximately 100 km. (62 miles) an hour. Owing to the speed restrictions in force, it was necessary to maintain a speed of 120 km. (74.6 miles) an hour over a large part of the run. The engine ran perfectly steadily both on the straight and on curves.

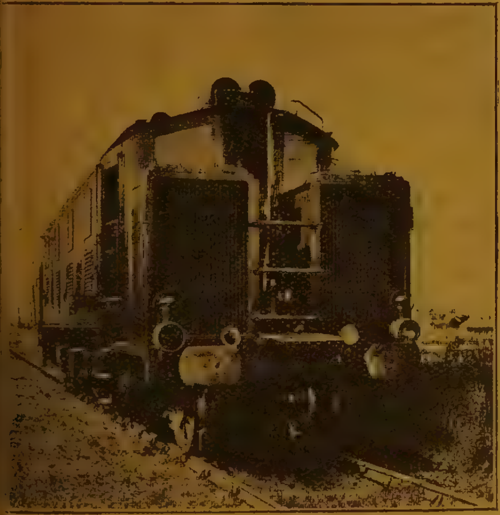


Fig. 11. — End view of the locomotive.

The fuel consumption was 1 240 litres (279.76 Br. gallons) of gas oil or 1.3 kgr. per km. (4.6 lb. per mile) run. The oil used was 60 litres (13.2 Br. gallons) or 0.07 l. par km. (2.4 Br. gallons per 100 miles) covered.

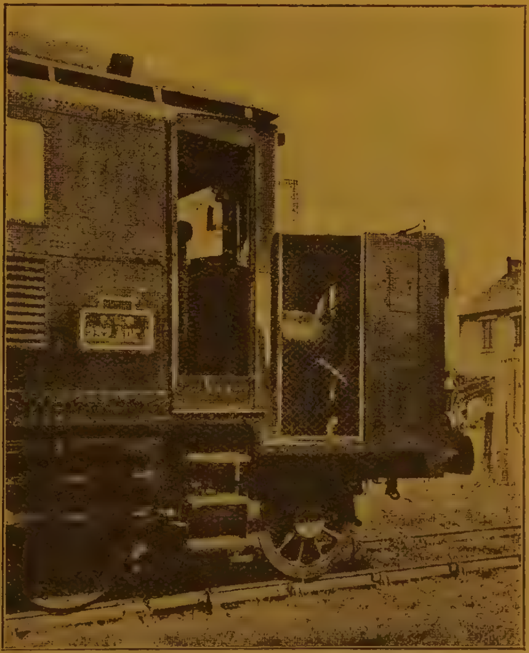


Fig. 12. — View of one of the driving compartments and of the radiator.

The tanks on the locomotive hold 2 200 and 720 litres (484 and 158 Br.

gallons) respectively, so that the engine could have run from Paris to Ventimiglia. In this connection it may be pointed out that most of the passenger trains from Paris to Ventimiglia change steam-engines five times en route.

This locomotive, which has already run 10 000 km. (6.210 miles), is finishing its trials on the Paris-Lyons & Mediterranean lines in France before being sent to Algeria, where it will be employed working fast light trains on the Algiers-Oran line.

[621. 43]

Diesel-electric locomotive layouts.

(Les Chemins de fer et les Tramways.)

Although the Diesel-electric locomotive has now shown itself as thoroughly satisfactory for shunting purposes and engines noteworthy for their wide range of speed and reliable running, of 800 to 1 000 H.P., have been built, there is still a stage in the development of this engine to be passed, namely the increase of power.

It is true that electric transmission and multiple-unit control enable a number of locomotives to be coupled together, and this is of value as trains of some considerable weight can be handled with the possiblity of the rakes with their motor units being separated as required to meet varying traffic demands.

Nevertheless, when express trains of some 800 tons have to be hauled, without splitting them up en route, the use of three engines, each of 800 to 1 000 H.P. (hourly rating) coupled together, cannot be recommended. Powerful locomotives, of 2 500 to 3 000 H.P. to begin with, must be built.

The progress made in Diesel engine design makes this possible. New designs of locomotives with the various motor units properly distributed must be considered. In addition, the electric drive must be so regulated that the Diesel motor automatically runs at its best output.

These problems have already been solved in varying ways. New patented devices appear monthly, improving on former designs. We describe below two designs, one relating to the distribution of the motor units on a rigid (non-articulated) locomotive, and the other to the automatic control of the electric transmission.

New layout of motors.

In most Diesel-electric locomotives the axles are driven in the same way as on electric locomotives, with the traction motors arranged with their centre lines horizontally, either between the driving axles or above them. In the case of high-power machines, these two layouts cannot be followed, in the first case because the rigid wheel base would become too great, and in the second the Diesel motor, which would also be much larger, could not be got into the available space.

The Diesel engine can be made more powerful either by increasing the number of cylinders, which makes the engine longer, or by increasing the power developed in each cylinder, which means an increase in the height of the engine (1).

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(1) See the articles by Mr. VAILLOT in the July, August, September and October, 1933, issues of *Science et Industrie* entitled « Evolution et développement des moteurs Diesel à deux temps et à double effet type M.A.N. » *(Evolution and development of two-stroke and double-acting Diesel engines of the M.A.N. type).*

Now, a rigid wheel base (non-articulated) high-speed locomotive should be of the 4-8-4 type at most; the rigid wheel base should, moreover, be as small as possible and the center pivots of the two end trucks should have some side play with spring centering gear, and the driving wheels themselves should be so designed that they will take the curves easily (side play of end pairs, thin flanges on intermediate wheels, etc.). The main frame, therefore, should be designed solely for strength and to suit the curves and not to give room for the traction motors. Whilst the length of the locomotive must be reasonable, the loading gauge limits the height and width available, so that if high-power double-acting Diesel engines are to be got in, the frame carrying the engine must be carried as low down as possible between the main frames.

These two factors led the « Machinenfabrik Augsburg-Nürnberg A. G. » to patent the following layout.

The Diesel engine is installed at the centre of the locomotive with its own frame brought down between the main frames while the vertical traction motors are fitted at each end of each corresponding driving axle. The power is transmitted through bevel gears and a quill which is spring-connected to the axle (as on high-speed electric locomotives).

By using vertical motors, sufficient power can be provided as there is ample room for long enough armature shafts within the loading gauge. The centre of gravity of the locomotive as a whole is raised at the same time.

Figures 1, 2 and 3 show this arrangement applied to a 2-D-2 (4-8-4) locomotive. The Diesel engine is carried above

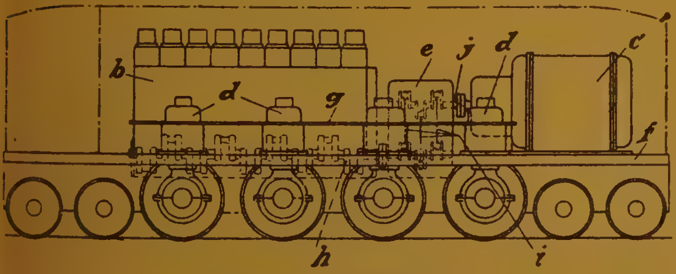

Fig. 1. — Elevation.

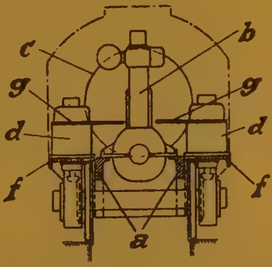

Fig. 3. — End view.

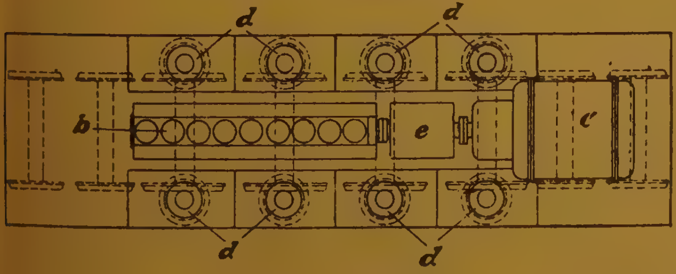

Fig. 2. — Plan.

M.A.N. Diesel electric locomotive.

LEGEND :

a) Main frame. — *b*) Diesel engine — *c*) Main generator. — *d*) Traction motors. — *e*) Multiple-crank drive. — *f*) Foot plate carrying traction motors. — *g*) Service platform.

the first three driving axles, its frame being carried between the main frames in such a way that the lower parts of the crank case are just above the axles.

The main generator is carried by the main frame. The armature shaft is in consequence on a different and higher level to that of the Diesel crank shaft. The two shafts are connected together by a special multiple-crank drive.

The eight traction motors, two per axle, one at each end, are arranged at the ends of the Diesel engine and transmission gear, and are carried on a footplate on brackets along each main frame plate.

On each side, half way up the Diesel engine, a service platform is provided parallel to the foot plate carrying the traction motors through which only the bearings of the latter project, so that the different parts of the Diesel engine can be inspected and attended to.

The new method of connecting the Diesel engine to the generator known as « multiple-crank drive » is intended to overcome the drawbacks of gear drive, namely : loss of power, reactions on the bearings if the shafts get out of line, and size and weight of the gears for high powers. This drive consists of two identical cranked jack shafts, one an extension of the Diesel crank shaft, and the other of the armature shaft. Each crank has a coupling rod, there being at least three coupling rods so that there shall be no dead centre. This drive is free from shocks and can transmit high powers.

In the present state of development of the Diesel engine, a Diesel locomotive of 2 500 to 3 000 H.P. is possible, at least as regards clearances, using a double-acting engine with driving wheels 1 m. 80 (5 ft. 11 in.) diameter and a driving wheel base of 6 m. (19 ft. 8 in.). The builder, the inventor, claims to have attained powers of 6 000 H.P. We should not like to go so far. The ventilation of the engine room and the traction motors, the water and oil radiators, the brake and control gear, and the many auxiliaries required to operate a 6 000-H.P. locomotive would need much thought. The maximum weight per driving axle is another factor to be considered. Then too, 6 000-H.P. locomotives do not appear to be called for, at least on European lines, by the operating departments.

If 600 to 1 000-H.P. Diesel-electric locomotives are now satisfactory, this power has not been clearly exceeded on any rigid wheel base locomotive in actual service. It would therefore be wiser to progress step by step, and begin by building engines giving 2 500 to 3 000 H.P. at the tread. Within such powers, the type of locomotive described above, with a double acting Diesel engine, is a practical proposition.

Automatic regulation device for Diesel-electric rail motor cars.

A Diesel engine driving a rail motor coach or a locomotive should work at constant load, about 9/10th of the nominal power, to give optimum efficiency and running. Considerable variation in load should only be made for short periods when running the rail motor coach. A good electric drive should therefore be so regulated automatically as to keep the Diesel engine working at nominal load independently of the driver. Most existing control gears act on the electrical transmission, or on the Diesel engine, or on both together through relays or rheostats, or valves controlling the fuel supply to the engine. They are not fully automatic in action.

The device described below, patented by the Allmänne Svenska Elektrika Aktiebolaget is intended to maintain the load on the Diesel engine constant, without any regulating gear such as relays or rheostats, by using a motor-regulator working under constant load and connected to the excitation circuit of the main generator. Thus, without using any regulating devices, the Diesel engine will work automatically at the constant power determined by the fuel injection pump, the driver having merely to control the latter when he wishes to alter the power of the engine to suit working conditions.

With this new arrangement the motor equipment of the rail motor coach or locomotive consists of the following components :

The Diesel engine (1);
The main generator (2) driven by the engine;
The traction motor or motors (5), arranged in series in the main generator circuit;
A constant-voltage exciter (7);
A motor-regulator (8) driven by the exciter and driving say the Diesel engine ventilating fan so as to keep its speed constant.

The main compound type generator has two sets of field windings : series windings (3) through which the current feeding the traction motors flows, and the independently excited field windings (4) in the exciter-motor-regulator circuit. The exciter driven by the main generator is shunt wound and consequently operates under constant voltage. This double method of excitation of the motor-regulator automatically regulates the load. This double excitation consists of : a field winding (9) connected to the terminals of the exciter, i. e. under constant voltage, and a field winding (10) through which the current from the main generator flows, which is in consequence subjected to the speed variations of the traction motors.

The working of this arrangement can be analysed as follows : The object to be attained is to operate the main generator at constant load whatever the speed of the traction motors, that is to say according to curve 11 (fig. 5) representing the equation $EI = Ct.$

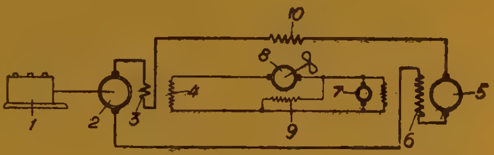

Fig. 4.

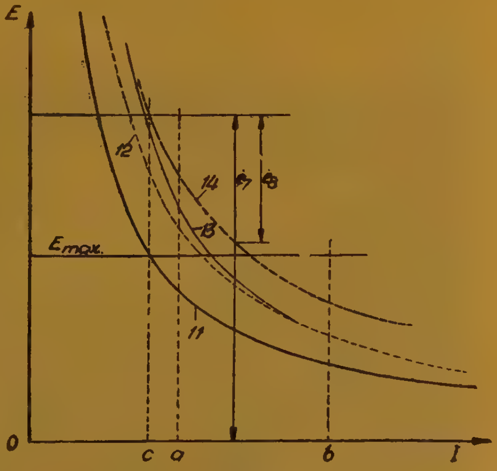

Fig. 5.

Fig. 4 and 5. — A. S. E. A. automatic regulating arrangement.

Theoretically it would be sufficient that the excitation of this generator varied as curve 12 which is also hyperbolic. To take the saturation of the machine into account, the variations in excitation must be altered and this results in curve 13. Then, the main generator being compound-wound, and these fields acting in the reverse direction, the current through the field windings can be modified when instead of curve 13 it follows curve 14. This latter more nearly follows the theoretical hyperbola 12 but requires greater current intensity to give the same voltages; this is, of course, the well-known back electro-motive-force effect.

Curve 14 can be considered as a reversed out of phase magnetisation curve. The solution of the formula $e = f(i)$ then becomes easy. The voltage e^7 at the terminals of the exciter being constant, all that is needed is to oppose it with the voltage e^8 at the terminals of the motor regulator; these voltages are produced respectively by the currents of intensity i^7 and i^8 through the armature of the exciter and of the motor-regulator. The resulting voltage $e = e^7 - e^8$ is the voltage at the terminals of the shunt windings of the main generator.

The variations in e^8 are the result of the variations in the current intensity absorbed by the traction motors since the same current passes through the field windings (10) of the motor-regulator. The shunt excitation (winding 9), under practically constant voltage, of the motor-regulator causes the displacement of the voltage curve given by the motor-regulator. It is set to compensate completely the excitation produced by the field windings (10) when the current intensity of the main generator corresponds to running conditions slightly faster than the maximum speed of the rail motor coach.

Thus, in the case of the current intensity corresponding to the abscissa *c* (fig. 5) the back voltage e^8 produced at the terminals of the motor-regulator is nil; the current intensity absorbed by the traction motors oscillates, however, between the limits shown at *a* and *b*. It is easy to calculate the dimensions of the winding 9 and to select the angular running speed of the motor-regulator in order to get the initial constants. The relation EI = Ct will then be obtained automatically, that is to say the Diesel engine will work under constant load. It should be noted that the speed of the motor-regulator can be regulated by altering the fan driven by the Diesel engine.

RECENT DEVELOPMENTS
IN RAILWAY PRACTICE.

[621. 43 (.44)]

High-speed streamlined Bugatti railcars on the Paris-Lyons and Mediterranean Railways.

(The Railway Gazette.)

In the summer timetables of the Paris, Lyons & Mediterranean Railway, there appear two very fast schedules each way between Paris and Lyons, and Paris, Vichy and Clermont-Ferrand, with the note that these will be brought into operation at a date to be announced. The Paris-Vichy section started on July 9. The services are to be worked by streamlined Bugatti cars and on the

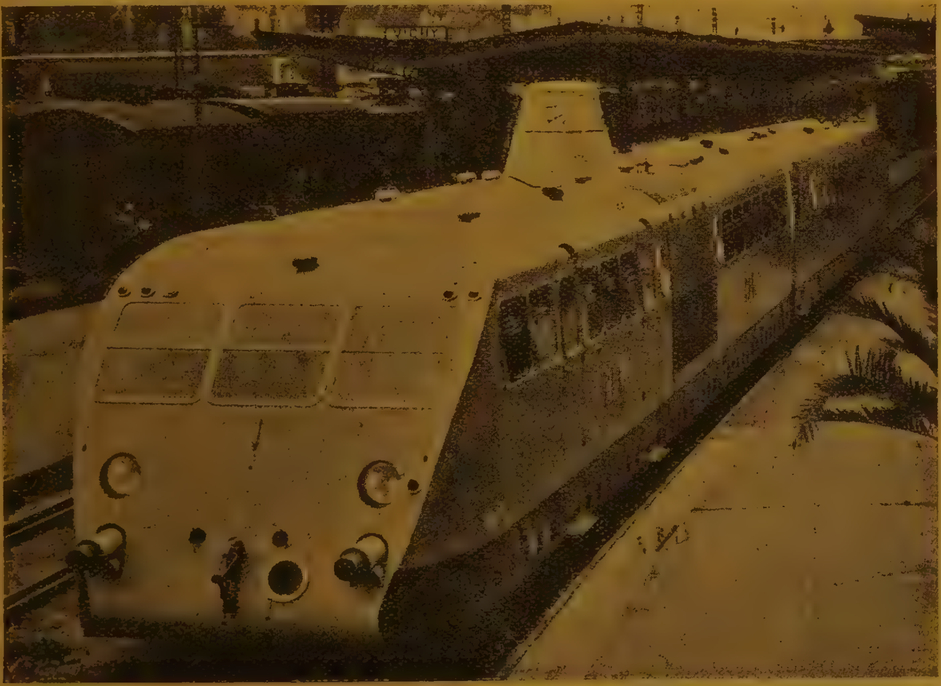

Fig. 1.

In this view the first of the new Bugatti streamlined double railcars, built for the fast service between Paris and Clermont-Ferrand and Lyons, is seen in Vichy station. It brings out the streamlining of the body at the front and sides, shows the taller conning-tower than on the earlier models, the new position of the radiators forming the outer wall of the engine cabin, and the little steps which serve to bridge the gap between the coach and the platform. All the windows are fixed and ventilation is effected by the devices on the roofs of the cars. Note too how the skirting is carried down almost to the ground to prevent the creation of air eddies round the wheels.

Paris-Vichy section of the Paris-Clermont service, on the up journey, the 226 3/4 miles between Vichy and the French capital are booked to be covered in 223 minutes, with four intermediate stops each of a minute in duration. The actual running time of 219 minutes therefore demands an average speed of 62.1 m.p.h. The down service is allowed 234 minutes for the corresponding journey, with the same number of stops. These timings make an interesting comparison with those of the down Cornish Riviera Express, allowed 244 minutes from Paddington to Plymouth (225 3/4 miles) with one intermediate stop of 3 minutes at Exeter. The throughout timings of the railcars between Paris and Clermont-Ferrand (261 miles) are 275 minutes and 260 minutes for the down and up trips respectively. There is a three minutes' stand at Vichy and Clermont, in each direction. The service will run on weekdays only and be limited to first class passengers.

Actually nine Bugatti railcars have been ordered by the P.L.M. Six of them are similar to the one-vehicle, two-bogie type that has been operating on the French State Railways for the past year between Paris and Deauville, and between Paris, Rouen and Havre; these light Bugatti railcars will, however, have only two motors of 200 H.P. each. The other three are termed *couplages*, indicating that they consist of two vehicles coupled together in order to get increased accommodation for passengers, and it is these which are being used for the services mentioned above. The seating in the P.L.M. *couplages* is not of the Bugatti reversible type, but is similar to that in first class Pullman cars, and the upholstery is in brown velvet. There are 36 seats in the motor car and 38 in the trailer, and they are arranged in pairs on the left hand side with single ones on the other side. They are arranged so that half face in each direction. Folding tables can be fitted in front of the

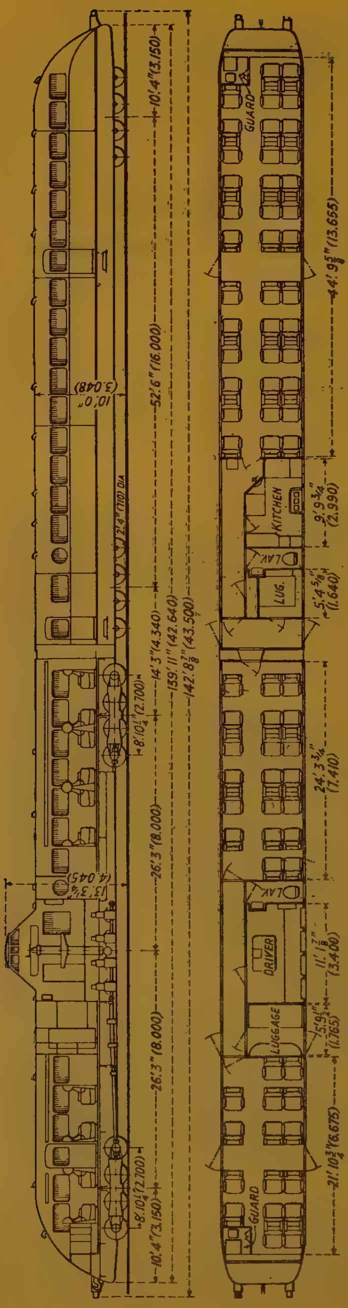

Fig. 2. — General arrangement drawings showing the location of the seating, the luggage compartments, the engine room, with the driver's cabin above it, the kitchen, the lavatories and the observation posts for the guard at each end of the vehicle.

passengers who require them. There is a small buffet-kitchen in the trailer-car, lavatories in each car and ample accommodation for luggage. The large windows enable a wide view to be obtained in almost any direction.

As regards the mechanical arrangements, they are generally similar to those described in *The Railway Gazette* of September 29, 1933 (1). The engine compartment is arranged in the middle of the leading carriage and it contains four 8-cylinder Royal Bugatti engines of 200 H.P. each, placed side by side transversely across the car, with two of the engines driving, through hydraulic clutches and reversing gearboxes, the forward bogie, while the other two are connected in similar manner to the other bogie. The fuel is a mixture of 55 % petrol, 30 % benzol and 15 % alcohol, carried in four double-skin, sheet-metal tanks, each of 285 litres capacity.

The bogies are arranged similarly to those described in *The Railway Gazette* of May 26, 1933 (1), that is to say there is the same scheme of mounting the axles so that the movement of any one of them has its amplitude reduced to one fourth by the time it reaches the pivot which connects the bogie to the vehicle itself. That, of course, refers to movement in an up or down direction, but lateral movement is designed to be diminished in much the same way by the utilisation of the four points of the frame of the bogie as a balance lever to secure a differential movement between the axles. The result is that very sharp curves can be traversed at really high speeds without any tendency to derailment.

There is another ingenious example of balancing in the arrangement of the cables for operating the internal expanding brakes, of which there is one on each wheel. There is a balancing lever between each pair of cables, another balancing-lever between each pair of balancing levers and another balancing lever divides the effort between the two just indicated. Thus the effort is evenly distributed over all the brakes of a bogie and actually there is another balancing lever above the last ones for each bogie, so securing complete compensation.

In the coupled vehicles for the P.L.M., the leading section carries the motors and is only streamlined in front and at the sides. The trailer is similar in outward appearance except, of course, that the streamlining is at the after end. The two are coupled together by a ball-type universal joint, while one side of the joint is mounted on a slide, to provide for lateral movement, controlled by a leaf spring on each side of it. The arrangement of the bogies on the trailer is similar to that of the driven car except that all the axles are simply carriers and take no part in the propulsion. There is one difference between the earlier types of Bugatti railcars and that is to be seen in the four radiators which form the wall on the near side of the engine room and extend from the floor line to the top line of the windows. All the windows are fixed so that there may be no eddies formed to have a slowing effect on the train, for the form of the train has been determined by air-tunnel experiments designed to secure a profile which shall offer the least resistance to passage through the air as well as being affected to the minimum extent by passing trains and when traversing tunnels.

The bodywork is of sheet steel on wooden framing and rubber is used to a great extent. The spigots which connect the body to the chassis are mounted in rubber pads and rubber is used under the tyres of the wheels and rubber bushes and washers round the bolts connecting the hubs to the other parts of the wheels. It will be noticed from the photograph that the conning-tower is of slightly different shape to the first design, being somewhat taller and with sides at an angle which is steeper than before.

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(1) See also *Bulletin of the Railway Congress*, May, 1934, pp. 475--479.

MISCELLANEOUS INFORMATION.

[625. 17 (.42)]

1. — Modern methods and appliances used in track maintenance on the London and North Eastern Railway.

(*Modern Transport.*)

During the last few years considerable extensions have been made in the use of mechanical appliances in connection with permanent way maintenance. The most important is the use of what is known as the motor economic system of maintenance, which requires a light motor-operated trolley running on the railway track to carry the lengthmen to and from their work. These trolleys are worked under one of two different systems of control, the most simple being when they are run and signalled in the same manner as an ordinary train. The alternative method is to arrange plug points at different parts of a section, these being electrically connected to the signal box. When the trolley is running on the track no train is permitted to enter the section, but when the trolley is removed from the track at one of these plug points, and a plug attached to the trolley is inserted in a socket in the plug post, the section is opened to traffic. The trolley cannot be placed on the line without withdrawing the plug, and, as this cannot be done without the permission of the signalman, it follows that the line is adequately protected.

The system is of particular value on branch lines where the traffic is light, and usually permits of one large gang maintaining track which previously required several smaller gangs, with a consequent reduction of manpower. A similar principle is applied when road motors are used, but the use of these for maintenance purposes obviously requires that roads should give convenient access to the line. The merit of this system is that railway traffic is not interfered with, the motor lorry being run at the most suitable time for the men, without relation to the train service. A combination of these two systems is effected on a portion of the West Highland line (L.N.E.R.) by utilising a road-railer. This is a vehicle which can run on either road or rail, and is of particular value on a line which has convenient roads adjacent to a part of the line only. On certain lines, the daily examination of the track is expedited by the use of a special light motor known as a « Speedster ». These machines are manually operated and of American design, their use having been established in the United States for track inspection and other purposes for several years. Their normal average speed when employed on track inspection or patrol is about 5 m.p.h., which is approximately twice the speed of the ordinary walking inspection. The « Speedsters » are worked between block posts as ordinary trains in accordance with a pre-arranged daily time-table. They are of light construction and can be lifted clear of the track, if and when necessary, by one man. Moreover, the outrigger with which they are provided is detachable and can easily be removed, thus enabling the machine to be placed in the guard's van of a goods or passenger train for either the outward journey or the return journey.

Repair appliances.

When renewing point and crossing work, electric or pneumatic tamping machines are often used, with considerable economy, as such work is generally carried out on Sundays, at high labour charges. The speed of relaying work has been increased by the use of power-operated drills, rail saws and screwing plant. Where it is necessary to clean the ballast, in order to improve the drainage of the track, an operation usually carried out by hand, electrical and petrol engine driven ballast-cleaning machines are used with good results. Various types of

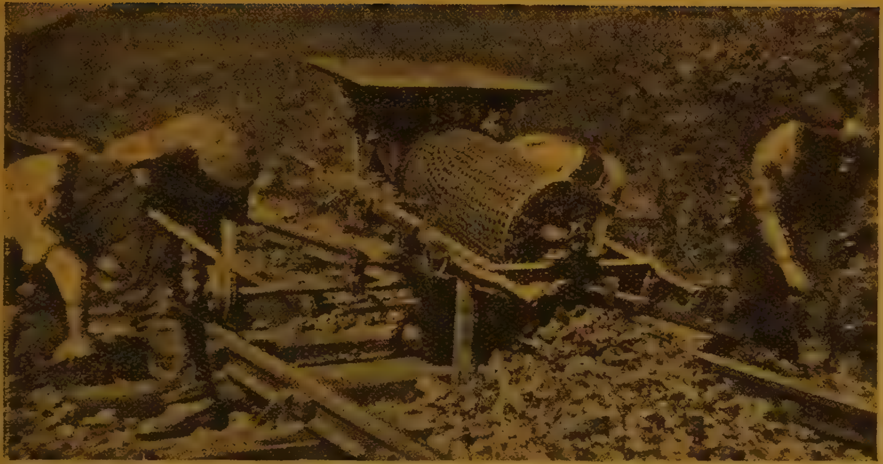

Fig. 1. — A feature of track maintenance on the L.N.E.R. is the mechanical riddling of ballast.

these machines operate in the different areas.

Considerable economies are obtained by building up worn crossings by electric arc welding, with the result that the process is now in general use. When the renewal of a crossing becomes necessary, it is due to the heavy wear on a small portion of the crossing, although the complete crossing has to be replaced. By welding new material on this heavily worn portion, the crossing is put in good order again, a particular benefit being that this is accomplished without dislocation of traffic, thus allowing work to be carried out during the week.

The electric welding sets used are of the portable engine driven type, of various makes.

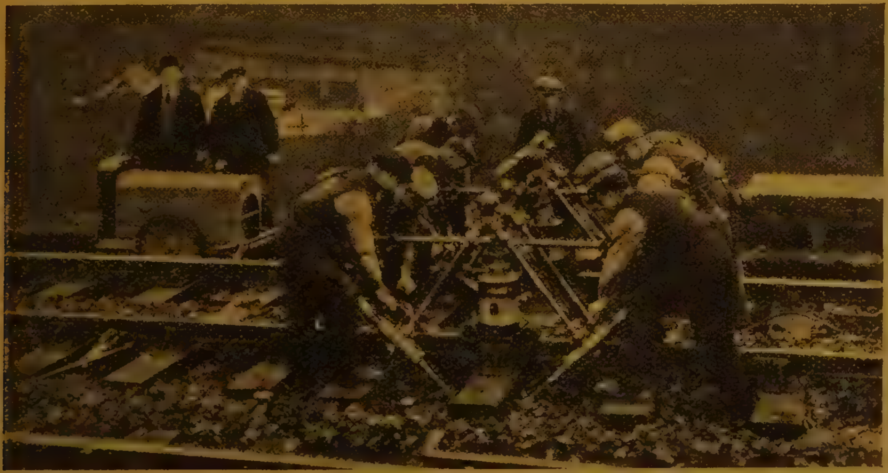

Fig. 2. — Sleeper packing apparatus in service.

Different types of electrodes are in use, these being made of special alloy steel to give hard-wearing qualities to the welded portion of the crossing. Whilst mention has been made of the chief mechanical appliances used in connection with permanent way maintenance on the London and North Eastern Railway, experiments continue to be made with other appliances, the use of which will be extended whenever it is economically practicable.

[621. 392 (42) & 625. 15 (.42)]

2. — Repairing cast manganese crossings by welding,

London and North Eastern Railway,

by F. E. HARRISON, O. B. E., M. Inst. C. E., Assistant Engineer, N. E. Area, London and North Eastern Railway.

(From *The Railway Engineer.*)

The network of crossings at the east end of Newcastle Central Station has always been an object of interest to the travelling public, and its maintenance and renewal from time to time has constituted a problem of some complexity to those responsible for its upkeep. Within an area of some 700 square yards there are 77 intersections, and the passage of through traffic and local traffic is computed to involve 1 066 movements over this concentration of crossings within the space of 24 hours.

Prior to 1912, the permanent way consisted of built-up crossings requiring abnormal attention from day to day, and the life of which reached an average of no more than six years. In that year the layout was realigned and renewed in Hadfield's Era cast manganese steel, such castings being particularly appropriate where so many of the crossings had to be of a special type, and where the increased initial cost was more than balanced by life prolonged and expense of maintenance reduced.

This layout lasted for twelve years, but during that period a considerable number of the castings had perforce to be replaced individually. In 1924 renewal in Hadfield's manganese castings, for practical purposes indentical with their predecessors, was carried out, but the crossings taken up, which had displayed every grade of wear, were not disposed of.

When in due course the daily passage of wheels was again making its effect apparent in increasing abrasion, consideration turned to the possibility of repairs, and repairs could be effected only by electric welding. Some experience to form a guide was forthcoming as a result of such procedure on similar crossings in places of minor importance, and it was decided to experiment upon a crossing where wear could not be more pronounced. To this end, a compound crossing, whose wear was intense, was taken from the old series still on hand and it was repaired by welding in order to ascertain if it would stand up to traffic for a few months. This crossing after treatment was put back in its previous position and again carried traffic for 12 months, and as a result of this trial it was decided to weld the whole of the layout.

Though at first the idea of welding in situ would seem attractive, such a proposition was ruled out by the intensity of traffic, and the conclusion was come to that to achieve an efficient result all the crossings must be removed temporarily for repair and replaced as a whole. To allow of this procedure it was necessary first of all to seek out the crossings of the previous series and repair them by welding to an extent sufficient to do duty whilst the newer set were being reconditioned.

This first exchange was made in March, 1933, some crossings of the older set being required to do duty for a maximum period of ten months before their second relegation. They will again be kept on hand for possible emergency use in the case of an individual crossing failing, so as to tide over the period that must elapse before a new one can be produced. The second replacement occupied four consecutive Sundays and was completed on February 4 last. The enterprise will be considered to have been a success if some years elapse before total renewal becomes a necessity.

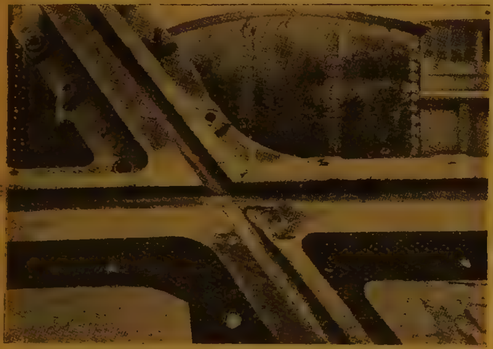

Fig. 1. — A crossing before welding.

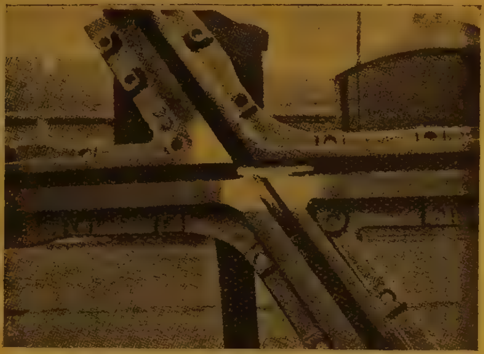

Fig. 2. — A crossing repaired by welding.

The whole of the welding was carried out in the railway company's permanent way works at Gateshead by A.C. static plant, except in the case of a few crossings which were dealt with by portable plant which happened to be working near by. With the exception of one or two crossings which were welded with other electrodes as an experiment, the whole of the building up was carried out with Quasi-Arc Mancross electrodes. Altogether 4 000 electrodes were used for the older set and 10 600 electrodes for the series now restored to the line, giving a consumption of four miles of electrodes altogether.

Opportunity was taken to allow for the intended requirements of signalling by grinding the ends of crossings for the insertion of insulation, and by welding on tabs of steel for the reception of bonds.

The economy of the project is reflected in the fact that £ 85 represented in 1924 the average price of each of the cast manganese crossings, while approximately £ 7 represents the cost in the shops of repairs by welding. There can be no doubt that the results of this enterprise will be watched with more than usual interest by all engineers responsible for permanent way maintenance.

[621. 138.5 (.42) & 621. 592 (.42)]

3. — Welded locomotive parts, London Midland and Scottish Railway.

(Engineering.)

Not so very long ago the suggestion that such a complicated part as a locomotive cylinder could be constructed by welding steel plates together would have been received as one hardly worth serious consideration. The technique of welding has, however, advanced so rapidly in recent years that cylinders fabricated in this way are now in operation. Three views of a cylinder with a piston valve casing so constructed are shown in the accompanying illustrations, and, it will be conceded, demonstrate the possibilities of the method in a very striking way. These cylinders have been fabricated at the Derby Works of the London Midland and Scottish Railway, and are fitted to the Company's locomotive No. 2424. This engine is of the standard 2-6-4 tank type, with cylinders 19 inches in diameter by 26 inches stroke. It should be mentioned here that welded construction has been employed purely in the nature of an investigation. The wide questions of reduction of weight, decrease in cost and running reliability cannot, of course, be answered by such data as may be gathered from one example. Weight, for example, is bound up with reliability, whilst costs are appreciably lowered by the mass production of any part. The engine, we understand, has, up till the present, given satisfactory results in running, and it will be interesting to see how far further experience and investigation will support the commendable enterprise of the railway company's engineering staff in exploring this departure from conventional practice.

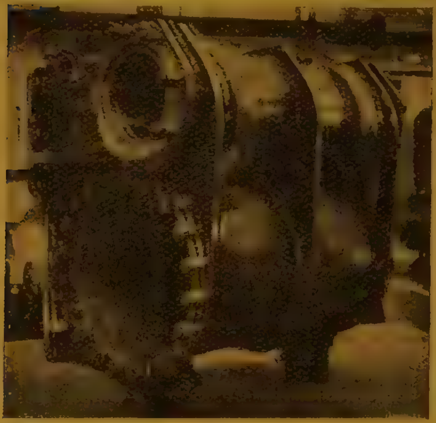

Fig. 1. — Completely welded cylinder.

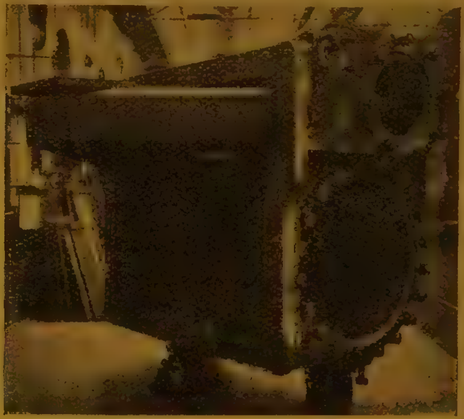

Fig. 2. — Rear view, showing exhaust pipes

Of the three views, figures 1 and 2 show the completed cylinder. The cylinder liner and the piston valve liner are both of cast iron, otherwise the whole construction is of welded steel, electric welding being employed. The valve casing assembly shown in figure 3 should be examined in connection with the other two views. The valve takes steam on its inside edges. The steam is supplied through the central pipe welded to the cylindrical casing. The holes for the ports are seen near the exhaust pipes, which unite as shown on the centre line. The ports themselves, that is, the passages between the casing and the cylinder, are not, however, in their correct position. Each port is in halves circumferentially and has been slid along the casing barrel to show the holes. They are, of course, welded over the holes and then occupy a position which, it will be seen from figure 1, gives an almost straight lead to the cylinder. It will be noticed that the circumferential joint has bevelled edges. The position of the exhaust pipes relative to the facing by which the cylinder is attached to the frame, is seen in figure 2. The openings seen in both figures 1 and 2 near the valve cover joint are formed in the valve liner. Welding has been also employed on other parts of the locomotive. Thus, the stretchers to the rear buffer beam, under the footplate, in front of the coal bunker, behind the fire-

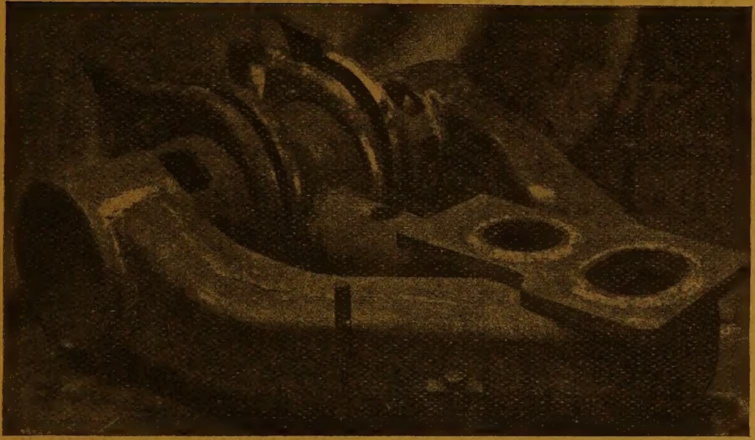

Fig. 3. — Assembly of valve casing, ports, etc.

box and smokebox, above the driving wheels, between the motion plates and cylinders, and for the Bissel truck swivel pin, were welded to the frames though the customary riveting was retained. A number of small details were also welded to the frames.

NEW BOOKS AND PUBLICATIONS.

[385. (01]

HOLMSTROM (J. Edwin), B. Sc. (Engineering), Ph. D. (Economics) A. C. G. I., Assoc. M. Inst. C. E., M. I. Struct. E. — **Railways and Roads in Pioneer Development Overseas :** A study of their comparative economics. — 1934, London. P. S. King & Son Ltd., Orchard House, Westminster S. W. I. — One volume (8 1/2 × 5 1/2 inches) of 304 pages, illustrated, with a number of tables. (Price : 15 sh. net.)

When there is question of setting up some method of transport in a new country, there are cases in which, owing to the nature, importance and regularity of the traffic expected, a railway is the obvious choice. In other cases, when the traffic is likely to be small and irregular or only likely to develop very slowly, it is possibly better to construct a road for motor traffic. Between these two extreme cases, there are many occasions in which it is necessary to study the best solution, and here there is need for technical knowledge to be able to decide the exact limits after which a railway will be the most economical solution of the problem. Account must be taken of the capital cost, and the expenditure on maintenance, renewal and working, both for the permanent way and the rolling stock, as well as many other factors, especially the industrial advantages a country derives from having transport facilities.

The object of this book is to show how statistical information taken from the reports of administrations or transport undertakings can be used to find the solution for some particular case or to draw up general rules.

The author, who is an engineer with experience of overseas countries, felt how useful the results of such an investigation would be when carrying out the preliminary survey for a proposed railway.

He has collected and classified, according to his own arrangement, a considerable amount of hitherto unpublished data relating to Asia, Africa, and other parts, with the object of finding out and establishing, for a given set of conditions, the sphere for transport by railway, by road, or by road and rail combined.

In the first part of his book, the author considers the nature of the different methods of land transport and the relationship between their economic and physical characteristics. He deals with three ideas he calls : the cost to the customer, the cost to the transporter, and the virtual cost. These three ideas form a statistical estimate of the whole expenditure, whatever it may be, required to introduce transport facilities and to give the country the indirect advantages to be derived therefrom. He attaches particular importance to the fact that part of the cost is incurred to aftain a given capacity (capacity variant) while another part of the cost depends directly upon the user (traffic variant); the comparative value of these two parts in the different methods of transport is often a very valuable criterion.

Parts II and III, which deal respectively with the railway and the road, develop a technique by means of which all necessary kinds of expenditure can be taken from the published statistics. Part IV gives comparisons and conclusions. The final conclusions in reply to the question : Upon what guiding principles should the transport policy of a new country be based? are of particular interest.

E. M.

[38 (09 (.42)]

SHERRINGTON (C. E. R.). — **A Hundred Years of Inland Transport.** (The Hundred Years Series, 1830-1933). — London W. C. 2, Duckworth, Editor, 3 Henrietta Street. — One volume (8 1/2 × 5 1/2 inches) of 376 pages. (Price: 15 sh. net.)

The author's object in this book has been to describe the history of transport in England during the hundred years since the opening to public traffic of the Liverpool and Manchester Railway in September, 1830. It is true that the Stockton and Darlington Railway was inaugurated with great ceremony five years earlier, but this railway was not originally intended for passenger traffic, and subsequent generations consider the opening of the Liverpool and Manchester Railway as an event of equal if not greater importance in railway history.

The railways naturally have pride of place in this book. At a time when they are experiencing difficult times on account of the severe road transport competition, it is interesting to see past events set out in their natural order and in the relationship connecting them together. A study of the evolution of the different methods of transport during these hundred years and their mutual interaction will make it quite clear that, even if circumstances have changed, there is nothing new in the problem of co-ordinating transport.

The purpose of this book is in no way didactic. It does not set out to enunciate principles or methods. Its only object is to relate the most interesting events in the history of transport and to show their influence on the social organisation of Great Britain. The author himself states that his object will have been achieved — and we may say that it has been indeed — if he has succeeded in making the reader understand in their proper perspective the events of the hundred years in question.

Whether he is dealing with the early period when the railway in its infancy was up against a hundred and one obstacles, or with the era of rapid development, when the railway gradually took the place of the road and the canal, or yet again with the period of prosperity just before the Great War, a perusal of this book will give the reader a very complete picture of the material conditions of the time in question, the economic data, the financial results, the legislative acts, the technical equipment, and the origin of the companies, their development, etc...

The book also deals with some ten periods which are characterised by particular features, the last of which, from 1920 to 1929, is the epoch of the reconstruction of the railways, their grouping into four great companies, but also the epoch of the ever increasing prosperity of motor transport.

The last years show the great efforts made to achieve coordinated transport. There is the Road Traffic Act of 1930 and, following that, the Road and Rail Traffic Act of 1933 which regulated road transport and gave the railway companies new powers. In the City of London all passenger traffic, apart from the main railway companies, i. e. the traffic carried by underground, tramway or omnibus is controlled by a single organisation, the London Passenger Transport Board.

E. M.

[693]

KALKOWSKI (T. J.), Engineer (reinforced concrete structures). — **Torkretnicwo. Betonowanie pod cisnieniem sprezonego powietrza i jego zastosowanie w budownictwie** (*Work carried out by means of the cement gun*). A pamphlet of 102 pages fully illustrated. Special issue of « Cement », vol. IV, 1933, Nos. 1, 2, 5, 7, 9 and 10, Warsaw.

This book, which is written in Polish, is a detailed description of the use of the cement gun. This method of working involves the injection of a mixture of cement and water by means of compressed air which applies the mortar under pressure.

The book consists of 102 pages with many photographs and drawings explaining the working of the apparatus, the operating method, and various examples of its use in new buildings or for repairing old masonry.

This little book, with its bibliographical index, might be of the greatest use to specialists of all countries were it not for the language in which it is written, which will be an insurmountable obstacle to many of them.

R. D.